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U.S. ARMY ELECTRONICS MATERIEL AGENCY  
CONTRACT NO. DA-36-039-SC-86726  
QUARTERLY REPORT FOR THE PERIOD  
OCTOBER 31, 1962 TO JANUARY 30, 1963

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**PRODUCTION ENGINEERING MEASURE**

**2N914 AND 2N995**

**QUARTERLY REPORT**

**FOR THE PERIOD**

**OCTOBER 31, 1962 TO JANUARY 30, 1963**

**OBJECT:**

**IMPROVE PRODUCTION TECHNIQUES  
TO INCREASE THE RELIABILITY OF  
SILICON PLANAR EPITAXIAL TRAN-  
SISTORS 2N914 AND 2N995**

**CONTRACT NO. DA-36-039-SC-86726  
ORDER NO. 19048-PP-62-81-81**

**PLACED BY**

**U.S. ARMY ELECTRONICS MATERIEL AGENCY  
PHILADELPHIA, PENNSYLVANIA**

**PREPARED BY: D. M. KOBRIN**

**APPROVED BY: P. W. HILL**

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## **SECTION I**

### **PURPOSE**

**Contract No. DA-36-039-SC-86726 is a Production Engineering Measure for improvement of production techniques to increase the reliability of 2N914 and 2N995 transistors. Processes being improved include.**

- a. Lead Attach**
- b. Preparation of Substrate for Epitaxial Growth**
- c. Header Plating**
- d. Particle Elimination**
- e. Die Attach**

## **SECTION II**

### **ABSTRACT**

**This third quarterly report presents a detailed narrative of the portion of the work accomplished in November and December of 1962, and January of 1963, in each task under PEM contract No. DA-36-039-SC-86726. Data, sketches, and photographs relative to the third quarter's work are appended to the discussion of each task.**

**SECTION III**  
**NARRATIVE AND DATA, CONCLUSIONS, FUTURE PROGRAM**

Each of the nine subsections which follow has been authored by the engineer in charge of the task described. Because the projects are relatively autonomous the narrative, conclusions, data, and plans for each project have been consolidated in these subsections, rather than presented in separate sections of the report.

A cover sheet precedes each subsection, identifying the material contained within it.

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**SECTION III**

**TASK 1A - CHANGE IN METAL SYSTEM**

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### SECTION III

#### TASK 1A - CHANGE IN METAL SYSTEM

W. J. Warren

#### PURPOSE

When gold wire is capillary bonded to small geometry aluminized devices, bond failure is liable to occur at temperatures above 200°C. At elevated temperatures gold diffuses into aluminum forming a dark colored intermetallic compound  $\text{Au Al}_2$ . The resultant removal of the gold from the bond area is believed to be the cause of the bond failure.

The purpose of this project is to determine the feasibility of developing a non-plaguing alternative to the gold wire-aluminum pattern metal system. It is desired that the new system should maintain the well established assembly systems as present used, in particular the thermal compression ball bonding technique.

#### BACKGROUND

Work prior to this quarter was carried out using three main approaches

1) Metalized layer: Gold over palladium

Wire : Gold

Problems were encountered at the lead bonding step. At temperatures greater than 300°C a liquid gold-silicon-palladium compound was formed which caused bond failure. Temperatures below 300°C were insufficient to allow the diffusion necessary for reproducible bonding.

2) Metalized layer: Silver

Wire : Gold, palladium or silver

Palladium wire did not bond to silver metal patterns. Silver wire bonded to silver patterns, but some problems were encountered owing to the tear drop shape of the balls fused from the silver wire.

Gold wire bonded satisfactorily to silver patterns. However, bond failure occurred after 40 hours of life testing at 300°C. This appeared to be due to the diffusion of dopants from the silicon through the silver to the gold.

3) Metalized layer: Palladium

Wire : Gold

Palladium metalized devices were produced with good electrical characteristics. Reproducibility of results, however, was found to be a major problem. There were three main drawbacks associated with the use of palladium:

- (a) Palladium showed a tendency to oxidize
- (b) Unless the alloying schedule was very strictly controlled, too much inter-diffusion between silicon and palladium occurred which produced a pattern to which gold wire could not be bonded.
- (c) The complete removal of the KPR or KMER maskant after the metal etching step was a problem.

PROGRESS FOR THE PERIOD

Three main approaches were tried during this period, these being developments of the approaches previously tried:

1) Metalized layer: Gold

Wire : Gold

In the previous quarter, gold over palladium metalized devices were made. It was found, however, that a low melting gold-palladium-silicon compound was formed in the lead bonding step which made it impossible to form satisfactory bonds.

It was resolved to omit the palladium layer since both the 2N914 and 2N995 devices contained gold prior to the pattern metalization step. Hence it seemed unlikely that the use of a gold pattern would adversely affect the electrical properties of the devices.

Satisfactory results were obtained at the Fairchild Diode Plant with the gold metalization of diodes. Gold metalizing techniques had been developed at the Diode Plant which appeared worth trying with the 2N914 and the 2N995.

2) Metalized layer: Silver over chrome

Wire : Gold

When bonded silver metalized devices were aged at 300°C in nitrogen, bond failure occurred after 40 hours. This was thought to be due to the diffusion of dopants from the silicon through the silver into the gold ball leaving a void beneath the ball. The resistance to oxidation of silver and the relative ease of bonding to gold wire, however, made it a desirable metal pattern material. It was hoped that, by introducing another metal between the silver and the silicon, a barrier could be formed to prevent diffusion from the silicon to the gold ball bond.

Chromium was tried as a silver substrate material for several reasons. Chromium is known to adhere well to silicon dioxide which is an advantage for many semiconductor devices. It has a very good abrasion resistance which allows films of considerable strength to be made. Work at the Fairchild Research and Development Laboratory on chromium-metalization has shown considerable promise; devices with ohmic contacts between the chromium and the doped silicon have been produced. The formation of an ohmic contact is believed to be due to the fact that the 2N914 and 2N995 devices both contain gold, and the gold provides a satisfactory chromium silicon bond.

3) Metalized layer: Platinum or palladium and alloys.

Wire : Gold

This was a continuation of the work done in the first two periods. Some experiments were tried with platinum alloys since platinum is similar in many respects to palladium, but has a greater resistance to oxidation.

The work performed this quarter and a discussion of the results is given below:

1) Metalized Layer: Gold

Wire : Gold

Some 2N995 wafers were gold metalized using the following process. 60 mg of gold were evaporated from straight tungsten filaments onto the wafers, which were heated from below by tantalum heater strips. The unwanted metal lying over the oxide was removed by gently rubbing the wafers with cotton buds soaked in trich-

lorethylene. This was easily done since the gold did not adhere well to the silicon dioxide. The wafers were then alloyed at temperatures above the gold-silicon eutectic (370°C) for very short times. The alloying time was found to be critical since too short a time permitted no alloying, whereas too much time allowed all of the gold to be soaked up by the silicon. The dice were attached to the header at 395°C for as short a time as was consistent with good bonding. Lead bonding was carried out at 325°C for 3 seconds. These low temperatures were used for die attach and lead bond operations in order that further diffusion between the gold and the silicon should be minimized.

Some gold metalized 2N995 devices are undergoing in-plant life testing for 1000 hours.

10 devices are undergoing storage at 200°C

5 devices are undergoing storage at 300°C

10 devices are undergoing power life testing at 300 mw.

10 devices are undergoing power life testing at 400 mw.

The devices were electrically tested after 500 hours and the following results were found.

(a) No open devices, caused by bond failure were found.

(b) All electrical parameters remained within acceptable in-plant specifications.

2) Metalized Layer: Silver over chromium

Wire : Gold

The process used at the Research and Development Laboratory formed the basis of the preliminary tests carried out, and is described below.

The chromium and the silver were evaporated from tungsten helical coils. The chromium was first evaporated onto the wafers which rested on heater strips at 600°C. When most of the chromium had evaporated the substrate heater strip was turned off.

Just before the end of the chromium evaporation, the silver evaporation was started. In this way a thin layer of a chrome-silver alloy was evaporated on to the wafer between the layers of pure chromium and pure silver. The existence of this intermediate layer was found to be important since it provided good adhesion between

the chromium and the silver. However, if the alloy layer was too thick then etching difficulties were encountered.

After the evaporation was completed, the wafers were masked with KPR and etched. The silver was etched with ferric nitrate solution and the chromium was etched with hydrochloric acid.

Preliminary tests were carried out for metalization work under the contract. It was found that with the power source at our disposal, tungsten wire of at least .030" diameter was needed in order to provide sufficient heat for chromium evaporation. Evaporations onto glass slides beneath the filaments were carried out in order to determine the optimum filament arrangement to provide a large area deposit of uniform metal thickness. Metal thicknesses on the glass slides were compared by taking resistivity measurements with the aid of a four point probe. Downward evaporation of chromium and silver from helical coils was found to yield non-uniform metal layers owing to the masking effect of the coils themselves on the evaporating metal. Best results up to this time have been obtained by using a chromium plated straight tungsten filament and a straight, three strand tungsten filament with clips of silver interwound between the strands. Heating of the substrate during the evaporation has been found to greatly increase the adhesion between the silver and the chromium layers; however, adhesion between the chromium and glass slide can be obtained even with a cold substrate.

Tests have been started on the evaporation of chrome-silver onto small geometry devices.

### 3) Metalized Layer: Platinum or palladium and alloys

Wire : Gold

At the end of the last period it was found that the evaporation of thick metal layers and alloying for 2 hours at 300°C caused good alloying between the palladium and the silicon, without allowing excessive palladium-silicon interdiffusion. Runs #45 and #46 were carried out this period with 3000 mg of palladium evaporated using

this alloying schedule. As in the last period considerable trouble was encountered in the removal of the KPR after metal etching. Also, in run #46, it was found that the aqua regia was attacking the palladium metal under the KPR.

In order to circumvent the etching problem, several evaporations were carried out onto wafers which had KPR over the oxide field prior to evaporation. After metalization, the KPR and excess metal were removed by boiling the wafers in trichlorethylene and ultrasonically cleaning them in acetone.

In run #47, KPR masked wafers were ion bombarded in the bell jar prior to metalizing in order to clean the wafers as thoroughly as possible. The wafers rested on a heated tantalum strip during the metal evaporation in order to increase metal-silicon adhesion. The surface of the KPR appeared very cracked after removal of the wafers from the bell jar. The KPR and unwanted metal were removed without difficulty. The metal over the emitter and base areas appeared contaminated. The contamination was thought to be dissociation products from the KPR caused by the ion bombardment.

In run #48, the same procedure was carried out as in run #47 except that ion bombardment was omitted. It was found that the heat from the tantalum substrate heater during evaporation caused such hard baking of the KPR that its subsequent removal was impossible. Neither ion bombardment nor substrate heating were used in runs subsequent to #48.

Palladium evaporation and short alloying steps were carried out on KPR masked wafers in runs #50 and #51, prior to KPR removal by the usual trichlorethylene and acetone treatments. The emitter and base metal appeared clean until wafer chips were heated during lead bonding, when pinkish and greenish films appeared; these films were thought to be due to residual KPR. It seemed likely that the alloying treatment prior to KPR removal increased the adhesion of the KPR and increased removal difficulties.

In runs #52, 53, and 54, KPR removal was carried out immediately after metal evaporation and before alloying. However, after each of the various alloying schedules which were attempted, colored films due to incomplete KPR removal were observed. Lead bonds made to the contaminated metal surfaces were not of great mechanical strength.

In runs #55-60, a platinum - 3% rhodium alloy was evaporated on to KPR masked wafers. The KPR and excess metal were removed with trichlorethylene and acetone prior to the alloying step. Lead bonds were easily made to the unalloyed metal (run #55) and the metal alloyed for 2 hours at 300°C (runs #56), but on pulling the bonds to destruction, failure occurred between the metal layer and the silicon. This showed that there was insufficient metal-silicon alloying. In each of these runs, however, the metal layer appeared clean after lead bonding, and no bond failures between ball and metal occurred, showing that the metal surface was free of KPR.

In runs #57, 58, and 59, alloying was carried out at 580°C for various times. After alloying for one minute, the metal surface appeared white. During lead bonding to a wafer chip some grey silicon could be seen projecting through the metal. After alloying for 3 minutes and 5 minutes, silicon could be seen in the metal to varying degrees. In each of these runs, when bonded devices were pulled to destruction, failure occurred at the metal-silicon interface. The appearance of silicon after alloying showed that platinum was similar to palladium with respect to the speed of metal-silicon interdiffusion.

In runs #61 and #62, the evaporation of a platinum - 10% niobium alloy was attempted. However, insufficient heat was obtained to evaporate much of the niobium. The wafers appeared to have a brownish film over the metal which hindered bonding.

25 palladium metalized 2N914 devices were subjected to 1000 hours of storage at 300°C. The devices were measured for  $I_{CBO}$ ,  $H_{FE}$ ,  $V_{CE}$ , and  $V_{BE}$  at 0 hours, 250 hours, 500 hours and 1000 hours. All of the devices except one maintained values of these parameters which were within specification. The single faulty device showed an emitter-base short after 500 hours.

Another batch of 25 palladium metalized 2N914 devices was subjected to 1000 hours of operating life at 400 mw. All of the devices remained within specification after 1000 hours with respect to the measured parameters, which were the same as those mentioned above for 300°C storage.



## CONCLUSIONS

The following conclusions were drawn with respect to the various metal systems which have been tried:

1) Metalized Layer: Gold

Wire : Gold

This system seemed feasible, the only drawback being the small tolerance limits allowed for the alloying time. The favorable storage and power life test results were encouraging.

2) Metalized Layer: Silver over chromium

Wire : Gold

Results to this time were promising since good silver-chromium-silicon adhesion could be obtained. The downward evaporation of chromium from a chrome plated straight tungsten filament gave a more uniform metal layer over the wafers than did downward evaporation from a helical tungsten filament.

3) Metalized Layer: Palladium, platinum alloys

Wire : Gold

Palladium metalized devices with good electrical characteristics, which survived storage and operating life tests, have been produced. However, serious fabrication problems existed which made it very difficult to obtain reproducible satisfactory results. The problems of working with palladium appeared also to apply to platinum.

It was therefore decided to discontinue work on the palladium and platinum metalization of devices, since gold or chromium-silver metalization appeared to be more promising.

## PROGRAM FOR NEXT PERIOD

Further work on the gold pattern-gold wire system will be carried out. Environmental tests on 2N995 devices will be undertaken and operating power and high temperature storage test will be completed.

More chromium-silver evaporations will be performed and attempts made to find the optimum metalizing conditions. Life and environmental tests will be carried out on completed devices.

**EXHIBIT 1**  
**PROCESSES AND TESTS USED FOR PALLADIUM AND PLATINUM ALLOY METALIZING**

RUN #	Metal Evap and Wt (mg)	Heater Strip on for Evap	KPR over Field for Evap	Alloy Temp °C	Schedule Time (mins)	Metal Appearance after alloy and etch	Step Where Bond Tests Made	Approx % Bonds	Pull Sample Size # Units			Tests Failed in Span			Failed Below Ball			Failed Below Metal		
									E	B		E	B		E	B		E	B	
45	3000mg Pd	No	No	300	120	KPR still over metal														
46	3000mg Pd	No	No	300	120	KPR still over metal	After Alloy Before Etch	95	15	15		15	13							2
47	2000mg Pd	Yes at 190°C	Yes	150	30	Brown	After KPR Removed	80	12	5						5			12	
48	2000mg Pd	Yes at 190°C	Yes	150	30	KPR Between E AND B														
49	1000mg Pd	No	Yes	None		White Metal														
50				300	10	White Metal	After Alloy	95	16	8		2	4					14	4	
51				300	30	White Metal	After Alloy	95	27	22		1	20					26	2	
52	1000mg	No	Yes	300	120	Grey Brown Due to KPR	After Alloy	95	18	10		7	8			11			2	

All evaporations were carried out onto 2N914 Wafers. Alloying was carried out in tube furnaces in a Nitrogen Ambient. Bonding tests were carried out at 345°C for 5 seconds.

EXHIBIT 1  
PROCESSES AND TESTS USED FOR PALLADIUM AND PLATINUM ALLOY METALIZING

RUN #	Metal Evap and Wt (mg)	Heater Strip on for Evap	KPR over Field for Evap	Alloy Temp °C	Schedule Time (mins)	Metal Appearance after alloy and etch	Step Where Bond Tests Made	Approx % Bonds	Pull Sample Size # Units		Tests Failed in Span		Failed Below Ball		Failed Below Metal	
									E	B	E	B	E	B	E	B
53				580	1	White Emitter Brown Base	After Alloy	30	6	6			5	5	1	1
54				900	1/3	Black										
55	1000mg Pt 3% Rh	No	Yes	None		White	After KPR Removed	100	24	20	5	8			19	12
56				300	120	White	After Alloy	100	7	7	2	3			5	4
57				580	1	White	After Alloy	75	12	19	1	2			11	17
58				580	5	Some Grey-Brown Most White	After Alloy	80	16	15		6			16	9
59				580	3	V Little Grey Most White	After	80	11	14	2	5			9	9
60				900	1/3	Black	After Alloy	75	9	10		3	9	7		
61	1000mg Pt 10% Nb	No	Yes	300	120	Light Brown	After Alloy	60	11	12		2	11	10		
62				900	1/3	Black	After Alloy	30								

**SECTION III**

**TASK 1B - SMALL BALL BONDING**

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**INTRODUCTION**

**NARRATIVE**

**CONCLUSION**

**PROGRAM FOR NEXT INTERVAL**

### SECTION III

#### TASK 1B - SMALL BALL BONDING

D. K. Myers

#### INTRODUCTION

This task was directed at improving the lead attach process by substituting ball bonding for the wedge bonding previously employed. The conversion was substantially completed during the first and second quarters. During this third quarter it was determined that the process described in the last report is satisfactory and requires no additional development work.

#### NARRATIVE:

Equipment developed under this task was presented in a series of photographs in the last report. During the third quarter, minor modifications in the equipment and operation procedure were incorporated. No substantial revisions were found to be required, and during the quarter it was decided to freeze the design.

The following items constitute the program for the third quarter as outlined in the second quarterly report.

- A. Torch: A titanium carbide torch as described in the previous report was evaluated for the second time with similar results. After less than eight hours use the torch had to be removed because of non-uniform ball size. The orifice was partially obstructed. Further evaluation has been abandoned.
- B. Capillary: Tungsten carbide capillaries for 1.1 mil diameter gold wire were evaluated along with continued evaluation for 2 mil diameter gold wire with respect to cost savings, reliability of gold to aluminum bonds, and improved yields. Problems of temperature control combined with a tendency of the capillary to stick to the aluminum pattern during the bonding cycle, caused the experimental (1.1 mil) capillary to appear unfeasible for small

geometry products. Continued work on 2 mil diameter gold wire bonded devices resulted in improved techniques and minimization of operator dependent variables. During the 4'th quarter, the 1.1 mil tungsten carbide capillary will be again evaluated on the 2N914 and 2N995.

- C. Wire Feed Mechanism: Incorporation of a small felt cleaning pad to clean the wire prior to entering the capillary was evaluated. In order to adequately clean the gold wire too much pressure had to be exerted by the felt pads resulting in non-uniform back tension on the gold wire, thereby, hindering the action of the wire feed mechanism. This mechanism must maintain enough back tension on the gold wire as it is unwound from the spool so that the gold ball is firmly held against the capillary as the capillary is indexed onto and retracted from the die. Quality Assurance inspection of incoming gold wire indicates a high degree of cleanliness. Therefore, the incorporation of the cleaning pads was not made on the production bonding equipment.
- D. Heater Design: Heater improvements as discussed in the second quarterly report have been completed and all production equipment has been modified.

#### CONCLUSIONS

The design of the gold ball bonding apparatus has been finalized and frozen. This portion of the task is considered complete.

#### PROGRAM FOR NEXT INTERVAL

During the fourth quarter the equipment currently used will remain under continual surveillance. It is not expected that further development work will be required or performed. Tungsten carbide capillaries for 1.1 mil diameter gold wire will be further investigated.

### **SECTION III**

#### **TASK 1C - OPTIMIZE CHARACTERISTICS OF .001" GOLD WIRE FOR CAPILLARY BONDING**

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**EXHIBIT 2 - TABLE SHOWING MECHANICAL PROPERTIES OF WIRES BEFORE AND AFTER  
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**EXHIBIT 3 - CHART, MEAN PULL STRENGTH vs ANNEALING TEMP.**

## SECTION III

### TASK 1C - OPTIMIZE CHARACTERISTICS OF .001" GOLD WIRE FOR CAPILLARY BONDING

W. J. Warren

#### PURPOSE

When .001" diameter gold wire is capillary bonded, it is found that a weak point is formed just above the ball bond. The heat from the hydrogen flame used to fuse the gold ball anneals and softens the wire above the ball. Failure of the bonded wire occurs at the soft, weak region above the ball in preference to the span of the wire.

The purpose of this project is to eliminate the weak spot near the ball during the capillary bonding of .001" diameter gold wire.

It was hoped that by annealing the wire, so that the mechanical properties throughout the wire were the same as those in the region of the ball bond, failure would occur in wire span. It was also hoped that, by having uniform mechanical properties, necking of the wire under stress at a weak point would be eliminated and hence an overall increase in the mechanical strength of the wire would result.

#### BACKGROUND

In the last quarter, hard drawn .001" diameter gold wire was annealed at different temperatures. Annealed and un-annealed wires were capillary bonded to aluminized dice. The mechanical properties of the wires were measured before and after bonding. It was found that the full strength of the annealed wire decreased with increasing annealing temperature, as was expected. The tensile strength of the bonded wire remained fairly constant with temperature owing to the limiting strength of the wire in the region of the ball softened by the hydrogen flame. At about 500°C the strength of the bonded wire became very similar to that of the unbonded wire.

#### PROGRESS FOR THIS PERIOD

During this period more wires were annealed at different temperatures, and more mechanical tests were performed before and after bonding. Tensile and elongation tests



were performed on the Instron machine. The dynamometer was not used for tensile testing since it was less accurate than the Instron.

The annealing of the wire was performed by pulling it through a Multiple Unit Hevi Duty Electric Co. furnace in the same manner as described in the last report. The wire was pulled through the furnace at a rate of 13"/minute.

Mechanical test were performed on four spools of hard drawn wire to see if there was much variation in properties from spool to spool. Several tests were performed on wire samples from the beginning of each spool. Annealing tests were performed on two of the spools.

Samples of wire in the hard drawn condition were taken from the center of these two spools and mechanically tested. The results of the mechanical tests performed on the hard drawn spools of wire may be found in Exhibit 1. The variations in full strength, and in the percentage elongation, were not great either from spool to spool or within a given spool.

The mechanical properties of the bonded and unbonded annealed wires may be found in Exhibits 2 and 3. Exhibit 3 also includes results for wires tested in the previous period. The same trends were observed as described in the last report. The strength of the unbonded wires decreased with increased annealing temperatures. The strength of the bonded wires remained approximately constant, corresponding to the strength of the weak spot above the gold ball annealed by the hydrogen torch during bonding. At temperatures greater than approximately 485°C, the strength of the span of the annealed wires became less than that of the area immediately above the ball bond; therefore at these temperatures failure of the wire was observed to occur in the span of the wires instead of above the ball.

The original objective of causing the gold wire to fail in span instead of above the ball has been fulfilled. However, the elimination of the preferentially weak spot above the ball did not result in an increase in the overall strength of the bonded wire as compared with bonded hard drawn wire. It was hoped that the elimination of the weak spot would cause a uniform reduction in area of the wire instead of necking, resultant stress concentration and failure, when stress was applied. This did not occur since

inevitable stress raisers, either external notches on the wire or internal defects such as dislocations, caused necking at resultant weak points on the wire span.

#### CONCLUSIONS

Annealing hard drawn .001" diameter gold wire at temperatures greater than 500°C caused the wire to fail in span instead of above the ball. However, no increase in the overall strength of the bonded wire was obtained.

#### PLANS FOR NEXT PERIOD

Since no increase in the overall strength of the bonded wire was obtained using this approach, it is resolved in the time remaining to try the effect of heat treatment of various immediately available gold alloy wires. It is hoped that this may provide an increase in the overall strength of the bonded wire.

TASK 1C - EXHIBIT 1

TABLE SHOWING MECHANICAL PROPERTIES OF DIFFERENT SPOOLS OF SECON .001" DIA GOLD WIRE HARD DRAWN

SPOOL NUMBER	POSITION IN SPOOL WHERE TEST MADE	PULL TESTS (INSTRON) TO UNBONDED WIRE			
		PULL STRENGTH (GRAMS) MEAN	RANGE	NUMBER OF PULLS	% ELONGATION MEAN RANGE
A	Front	16.7	16.4-17.0	3	.58 .55-.6
	Middle	15.6	13.0-16.5	5	.52 .5 -.6
B	Front	16.3	16.0-16.5	3	.58 .55-.6
C	Front	15.6	15.2-16.3	4	.55 .5 -.6
	Middle	16.2	15.3-16.6	4	.5 .5 -.5
D	Front	16.5	16.0-17.0	3	.48 .43-.5

TASK 1C - EXHIBIT 2

TABLE SHOWING MECHANICAL PROPERTIES OF WIRES BEFORE AND AFTER CAPILLARY BONDING

SPOOL NUMBER	ANNEALED CONDITION	PULL TESTS (INSTRON) BEFORE BONDING				BONDED PULL TESTS (INSTRON)			
		PULL STRENGTH (gms)		NUMBER OF PULLS	% ELONGATION	NUMBER BONDS PULLED	MEAN PULL STRENGTH (g)	RANGE PULL STRENGTH (g)	
		MEAN	RANGE						
	583°C	5.4	4.3-6.4	6	8.2	6.0-9.5	9	5.8	5.4-6.1
	422°C	6.3	5.9-6.6	4	9.0	7.5-11.0	10	6.7	6.1-7.1
	485°C	5.5	4.8-6.2	3	6.7	4.8-10.0	22	6.0	3.7-7.1
	538°C	4.9	4.7-5.1	5	6.2	5.2-7.8	22	6.0	3.5-7.5
	388°C	6.8	6.7-7.0	4	9.8	8.5-11.0	19	6.4	5.3-7.3
	383°C	6.7	6.5-6.8	5	10.1	8.4-11.2	20	6.1	5.2-6.8
	343°C	7.2	6.9-7.4	4	10.5	9.0-12.5	18	6.4	4.8-7.0
	209°C	8.4	8.2-8.4	5	3.7	3.0-4.0	18	7.1	5.3-7.8
	600°C	5.3	5.2-5.4	2	5.4	4.6-6.2			

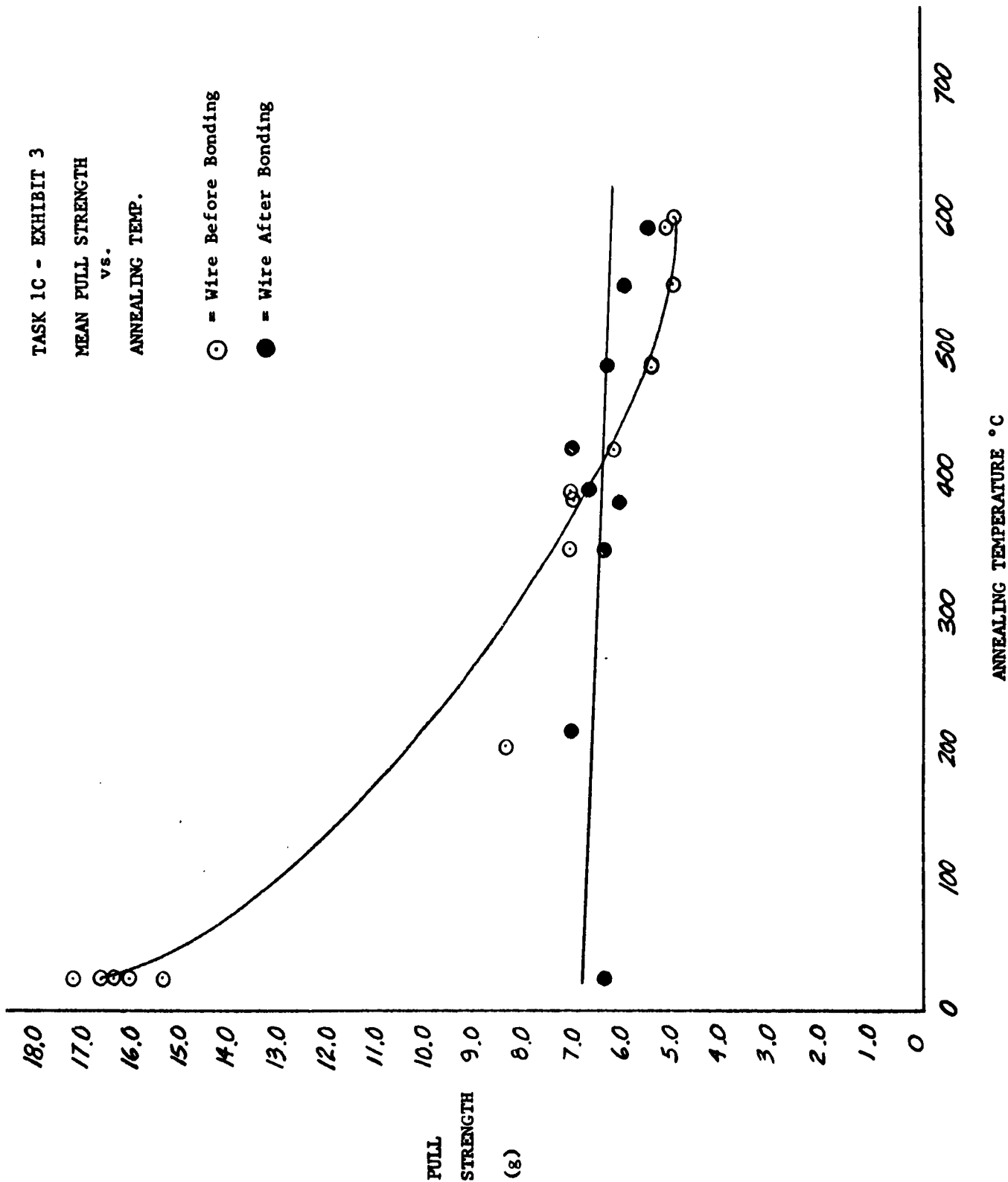
# TASK 1C - EXHIBIT 3

MEAN PULL STRENGTH  
vs.

ANNEALING TEMP.

○ = Wire Before Bonding

● = Wire After Bonding



**SECTION III**  
**TASK 1D - ULTRASONIC BONDING**  
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**PURPOSE**

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SECTION III  
TASK 1D - ULTRASONIC BONDING

E. R. Hippert

**PURPOSE**

The objective of this work is to develop and evaluate a method of bonding small wire to the metallized transistor surface by means other than the thermo-compression technique. The method should incorporate the following properties:

1. Be relatively insensitive to the surface condition of the two metals joined (metallic oxides and trace impurities).
2. Not have a critical bonding temperature, cause mechanical deformation of the die, or require long bonding times.
3. Be adaptable to small contact areas and give a weld with no residual contaminant formation.
4. Be reproducible and easily operative.

Ultrasonic bonding reasonably fulfills the above criteria and has been chosen for investigation.

**BACKGROUND**

In the first period, ultrasonic bonding was performed on aluminized dice using .001" 1% Si-Al wire. However, these bonds were not of reproducible high mechanical strength. In the second period it was determined that ultrasonic bonds can be produced between .001" 1% Si-Al wire and aluminized dice which are mechanically stronger than thermal compression wedge bonds. In addition, it was noted that highly annealed wire is weaker in the span of the wire than at the bond; therefore, hard-drawn wire is preferable to highly-annealed wire.

**PROGRESS**

Using a flat-faced tungsten carbide wedge (similar to one used in thermal compression wedge bonding) and .001" 1% Si-Al wire the following bonding results were obtained on small geometry units (similar to 2N914's):

(a) 12 base bonds showed a mean tensile strength of 6.0 gms.

(b) 13 emitter bonds showed a mean tensile strength of 5.6 gms.

All bonds broke at the angle (area immediately adjacent to the bond area). The settings used were:

Resonance 44, Power .0002 watts, Time 1.3 sec., and Force 30 gms. Reducing time to 0.6 sec. and the other variables held constant, the results were:

(a) 30 base bonds showed a mean tensile strength of 8.0 gms.

(b) 30 emitter bonds showed a mean tensile strength of 8.0 gms.

These bonds were made successively, and again, all broke at the angle. It was planned on the basis of this to make 100 consecutive bonds (again using device similar to 2N914) and evaluate their tensile strengths in order to determine repeatability. Again, hard drawn .001" 1% Si-Al wire, a flat wedge (see exhibit I for wedge description), and 0.6 sec. bond time; the mean tensile strengths were:

(a) 8.6 gms. on 50 base bonds

(b) 8.4 gms. on 50 emitter bonds

(c) 8.5 gms. on 100 bonds (bases and emitters combined)

In this test, 94% of the bonds broke at the angle (see exhibit II).

Tests designed to compare the strength of conventional thermal compression wedge bonds with ultrasonic bonds yielded the following data:

(a) 25 ultrasonically bonded 2N706's showed a mean tensile strength of 7.8 gms.

(b) 25 thermal compression bonded 2N706's showed a mean tensile strength of 6.3 gms.

(c) 25 ultrasonically bonded 2N917's showed a mean tensile strength of 6.6 gms.

(d) 25 thermal compression bonded 2N917's showed a mean tensile strength of 3.5 gms.

(e) 25 ultrasonically bonded 2N709's showed a mean tensile strength of 7.0 gms.

(f) 25 thermal compression bonded 2N709's showed a mean tensile strength of 3.8 gms.

Of each device type mentioned >96% of the bond failures occurred at the bond angle, demonstrating good wire to pattern adherence. All bonds were made with the



sonotrode described in exhibit I, and under the following conditions:

- (a) for the 2N706's; Power .202 watts, Resonance 44, Time .17 sec., Force 23 gms.
- (b) for the 2N917's; Power .202 watts, Resonance 44, Time .38 sec., Force 13 gms.
- (c) for the 2N709's; Power .302 watts, Resonance 44, Time .38 sec., Force 13 gms.

In conformance with a special test (see exhibit III) designed to evaluate ultrasonic and thermal compression bonding, the following resulted:

- (a) 220 of 235 2N706's were ultrasonically bonded
- (b) 138 of the 200 in (b) were lead welded
- (c) 238 of 250 2N917's were ultrasonically bonded.

The excessive fallout in (b) was attributable to work-hardening of the wire during ultrasonic bonding and subsequent difficulty in lead welding due to spring action of the wire. The problem was resolved by annealing the devices for 10 min. at 300°C in a nitrogen atmosphere immediately after ultrasonic lead bond.

#### CONCLUSIONS:

To this point, ultrasonic bonding appears:

1. Feasible on aluminum wire, aluminum pattern small area devices.
2. Reproducible on small sample lots.
3. Encouraging enough to warrant further investigation (see exhibit III)
4. Possible using a flat-faced tungsten carbide wedge and hard drawn .001" Si-Al wire.

#### PROGRAM FOR NEXT INTERVAL

The work done in the next interval will essentially be determined by the test results noted as the devices are processed through each phase of the special test scheme shown in exhibit III. Processing of devices will be expedited in accordance with the following estimated schedule:

- 1) Process die to lead bond by Production - 1 week
- 2) Bond through classification (normal prod cycle) - 2 weeks
- 3) Classification through 250 hours life - 3 weeks
- 4) Classification through 500 hours life - 5 weeks
- 5) Classification through 1000 hours life - 11 weeks
- 6) Data analysis to autopsy of rejects - 1 week

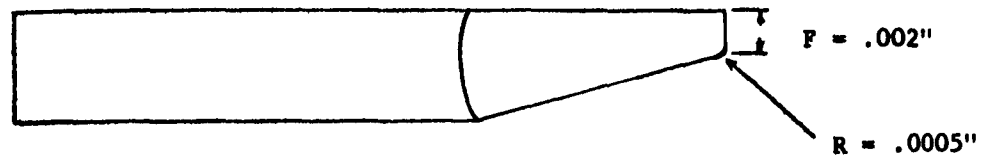
Upon completion of life test data and analysis thereof:

250 hours life, March 20, 1000 hours life April 30.

TASK 1D

EXHIBIT 1

SONOTRODE CONFIGURATION

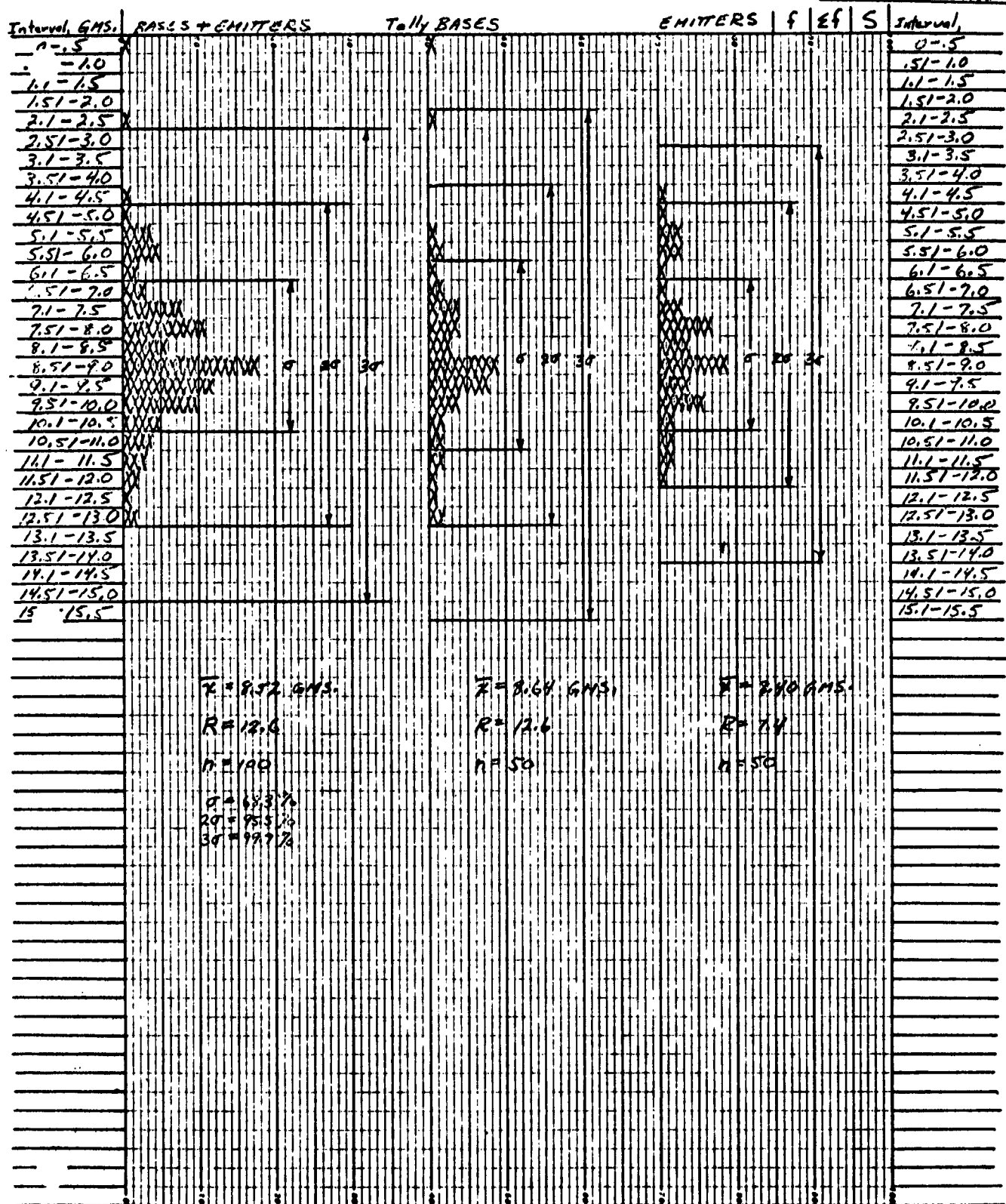


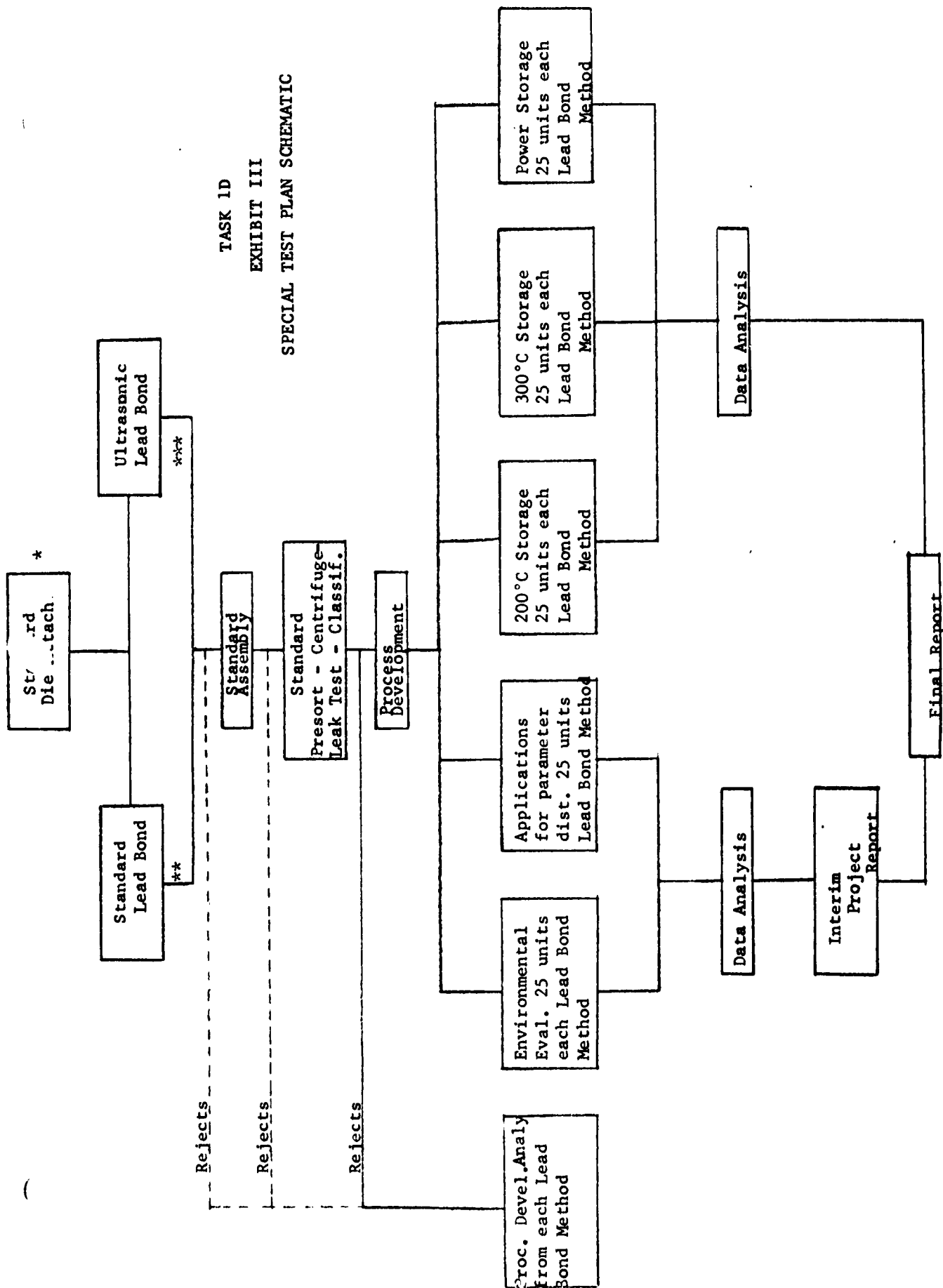
# FREQUENCY DISTRIBUTION CHART

EXHIBIT II  
EXPERIMENT ULTRASONIC BONDING  
DEVICE 2N706

TASK 1D  
EXHIBIT 2  
PULL STRENGTH

RUN-001 - 170 Si-Al  
WIRE





\*Start 500 units Total: Require 250 good units (125 of each lead bond method) total out of classification on each device type.  
 \*\*Identify by red dot on bottom of header.  
 \*\*\*Identify by green dot on bottom of header.

**SECTION III**

**TASK 1E - DYNAMIC AND STEP-STRESS TESTING**

**CONTENTS**

**SUMMARY OF WORK IN THIS PERIOD**

**SHOCK**

**CONSTANT ACCELERATION**

**STEP STRESS**

**PROPOSED DEVIATIONS FROM PROGRAM OUTLINE**

**EXHIBIT 1 - TYPICAL PHARMACEUTICAL CENTRIFUGE ROTOR**

### SECTION III

#### TASK 1E - DYNAMIC AND STEP-STRESS TESTING

J. Corzine

##### SUMMARY OF WORK IN THIS PERIOD

Extensive tests have been conducted on the high "G" level shock equipment this quarter. These tests have been very enlightening although lengthy and sometimes disappointing. It is evident now that technology in the high "G" level shock area (10,000 "G" and above) was not as advanced as was thought in the industry. At least one manufacturer is delivering a shock tower advertised as capable of 15,000 "G" shock. After exhaustive testing, we find that this tower cannot attain 15,000 "G's" without "ringing" or rebounding "G" levels of 30% or more of the original shock level. Several government agencies are specifying that "ringing" will be no more than 20% of the original shock level. This will be discussed in detail later in this report.

The Step-Stress Program is 70% completed at this date. This type of testing has presented no problems. Phase II of Constant Acceleration has been completed; however, it is in the process of being rerun due to an error found recently in the calculation of RPM to "G" levels.

##### SHOCK

During acceptance testing of the new shock tower, repeatability and ringing were the major problem areas evident. The replacement of the actuating cylinder and the addition of an oak pallet/on which to mount the tower combined to resolve the repeatability problem. The installation of the new cylinder assembly alone did not resolve this problem. Engineers from the tower vendor worked in conjunction with us on this. After many extensive tests it was virtually accepted that this particular shock tower would not repeat itself at "G" levels above 15,000 "G's". Prior to making the decision to return the tower and start testing with a new one, a tour of the vendor's facility

revealed that the towers were assembled on oak pallets and remained on these pallets during checkout testing. The quick installation of our tower on a pallet solved the remainder of our repeatability problems.

This tower was designed with a braking mechanism to dampen rebound "G" forces (ringing). However, ringing was apparent in the system during the repeatability tests and we started concentrating on this problem after solving the repeatability issue. No solution seemed to work. A crack in the 2,000-lb. concrete casting around the tower became apparent during the early tests. This crack progressed down the vertical axis on the front of the casting and has now started down the back of it. It is thought this crack was expanding upon impact and producing the "ringing" by the expanding and contracting at the impact of the head of the tower. After some research, it is thought that perhaps no shock tower of this manufacture is not cracked, either by repeated use or by some defect in the curing of the concrete block. The appearance of the crack prompted some calculations as to the mass required to absorb the energy generated by tests above 10,000 "G's". Calculations reveal that more than 2,000 pounds of concrete is required to absorb the energy generated by the shock tower at these high "G" levels. It is also thought that due to the high costs incurred by the vendor in shipping this heavy equipment that there is a tendency to use lighter materials in the concrete (i.e., cinders in place of rock). Fairchild is now in the process of ordering another shock tower to be shipped without the concrete block. Four-thousand pounds of concrete will be poured around the cylinder assembly (double the original weight) which will be large enough to absorb the energy generated by these high "G" level tests. We believe that this will cure the "ringing" problem.

It should be noted that some government agencies favor the "ringing" during shock tests as it is felt that this more closely approximates the "G" forces found in an actual environment (rebound "G" forces being present in impact or crash situations). Other agencies require that "ringing" does not exceed 20% of the original "G" force. ( In light of these views, we are conducting the shock tests under this contract with "ringing" present during testing.

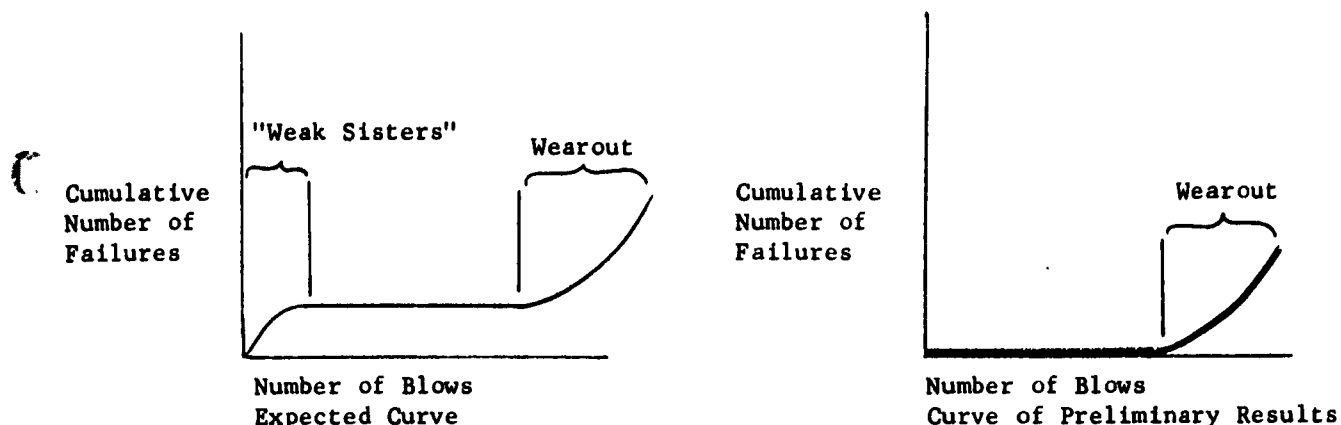


Calibration of shock equipment at high "G" levels is not as advanced as we thought at the onset of this contract. Our tests brought to light that technology in the accelerometer field was in a "gray" area above 10,000 "G's". Vendors were advertising equipment available to conduct tests in the areas discussed. Some of this equipment is qualified and delivered with an Endevco 2222 accelerometer attached. Our tower was delivered with this particular device. Our initial tests were conducted at an indicated 15,000 "G's".

Fairchild's Environmental Lab maintains a close relationship with other labs working on research in similar areas. The Sandia Corporation indicated in December of 1962 that test that they were conducting indicated the Endevco 2222 should not be used for high "G" level shock. Their test showed that the No. 2225 device was much better suited for this type of test. We immediately procured a No. 2225 accelerometer and found that the 15,000 "G" tests we had originally run with the No. 2222 were actually at 8,000 "G's". Fairchild was not alone in being misled in this area. The vendor and a great number of other labs were using this type of calibration. To further complicate matters, the Sandia Corporation presented a paper<sup>1</sup> at the seminar they conducted at Albuquerque, New Mexico, January 21-25, 1963 which indicates that even the No. 2225 accelerometer should not be used above 5,000 "G's". This paper also stated that only the No 2225M2 device should be used in the higher "G" levels. We are now in the process of obtaining a No. 2225M2 accelerometer before resuming shock testing.

Tests to date at high "G" levels (exact force obviously unknown) indicate that the curve that we proposed to find with shock testing may not exist. We expected a curve with two knees to become evident, one knee showing the "weak sisters" failing and the other showing the "wearout" or complete failure of the sample. With the tests run to date, we do not find the first knee; however, we do find the latter.

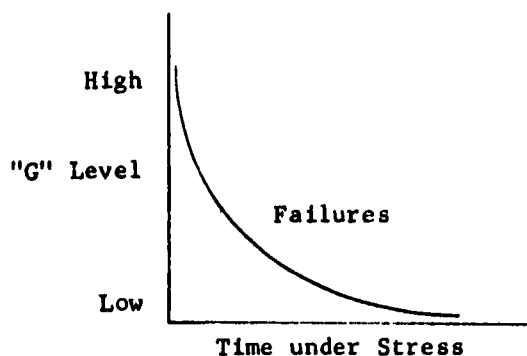
<sup>1</sup>Seminar on Environmental Testing conducted by the Sandia Corporation at Albuquerque, New Mexico, January 21-25, 1963. Paper presented by C. M. Warthen and A. B. Anderson. Subject - "Recommended Accelerometers"



The lack of "weak sisters" is thought to be the effect of the 20,000 "G" constant acceleration test that these units underwent on the Production Line. This test probably detected all of these weak sisters that we expected to see on the shock test. We will conduct more tests of small sample sizes and if the above theory is justified, we propose to run a sample of enough units to be of statistical significance at a high "G" level (approx. 10,000 "G") to establish average number of blows to failure. We will rerun a sample of the same size of the improved device to show an improvement in the mechanical strength of the new device. We feel that due to the lack of technological knowledge in the high "G" level range and the apparent lack of hoped-for results that the units committed for shock testing can be better utilized in other tests. Our thinking at this time is that a large sample size on Operating Life for very extended periods may provide better results to compare devices or processes. If more tests tend to prove out this point, we will submit a proposal to modify the second half of this test program.

#### CONSTANT ACCELERATION - PHASE II

An error was found in the calculations of RPM to "G" forces after we completed Phase II of this test. We are now in the process of rerunning the test. The results from the first run, although not entirely accurate, seem to indicate that there is no sharply defined "G" level at which to test for short periods of time as a screening process. We had anticipated a curve plotting failure versus time to resemble the following:



When tests were conducted over a large "G" level range and a large graph was plotted, this seems to be true. When trying to establish a sharply defined area, however, with numerous tests over a spread of 20,000 "G's", the results look more like a scatter plot. Testing will be continued to establish the exact curve and final results will be included in the next Phase Report.

When screening devices at high "G" levels, the rotor design becomes a problem. Pharmaceutical firms were the major users of centrifuges in past years, and vendors were geared to supply needs in this particular area. When environmental test labs came to the forefront, much of the previous hardware in this field was adopted. When testing at low "G" levels, this hardware has proven adequate in most cases for environmental testing. Inexpensive inserts to accomodate the particular device to be tested were designed to fit the pharmaceutical type rotors available. This worked satisfactorily at low "G" levels. Several small semiconductors, for example, could be placed into each insert of a pharmaceutical type rotor and centrifuged. Exhibit one illustrates what happens when this same hardware is operated at high RPM (higher "G" levels).

The space occupied by a device in the insert has a tremendous effect on the "G" level it experiences. At the RPM noted there can be a 32,000 "G" force difference in the positions a unit may occupy in the insert. This is not astounding information because the hardware used was simply not designed for this type of testing. As can be seen, the sample size that can be tested at a given high "G" level is greatly reduced. The cost of the design and stress analysis needed to provide rotors to test devices at high "G" levels is appreciable. This must be done, however, due to the limitations of existing hardware.

#### STEP STRESS (POWER AND TEMPERATURE)

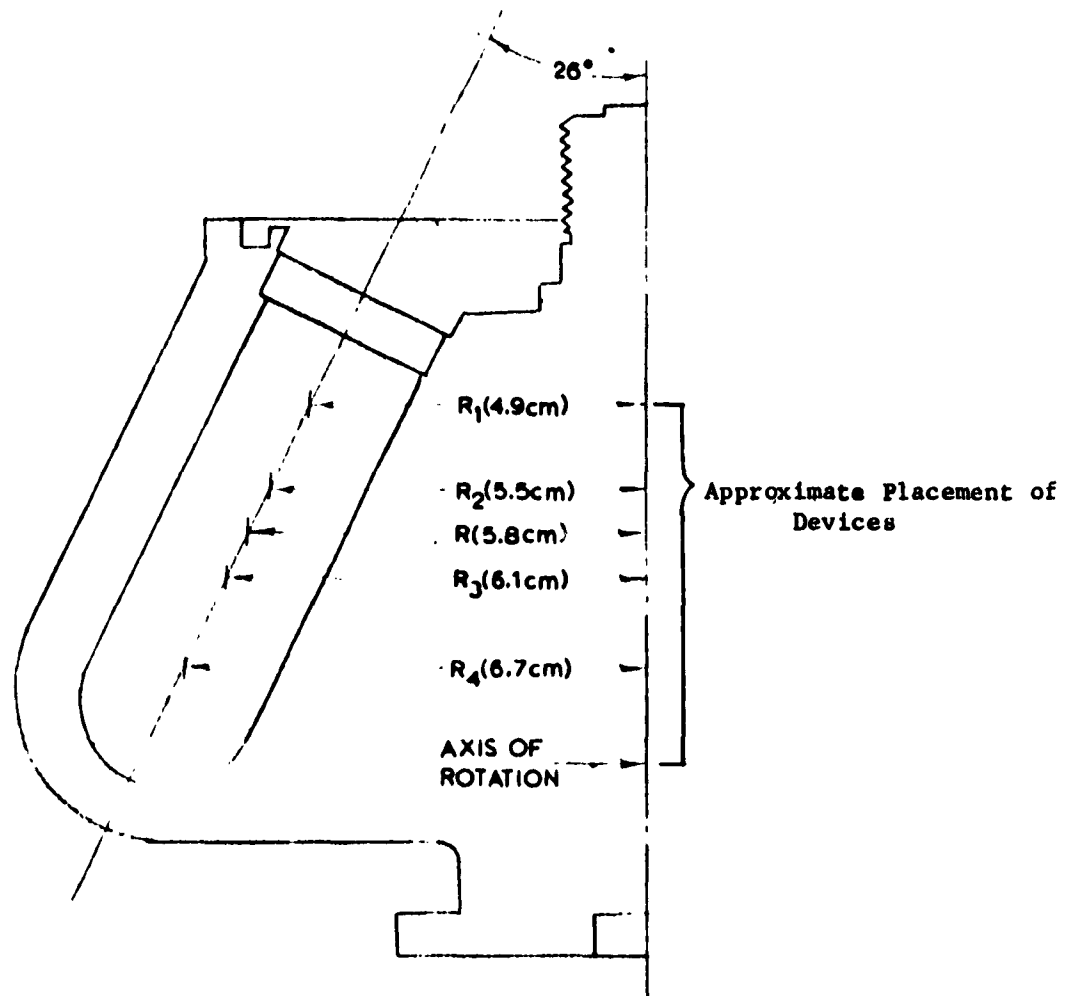
This test is progressing as planned. There are increasing indications that this type of test is not applicable to silicon devices. This project has had no catastrophic failures to date; and other information available in this area seems to indicate that when the junction temperature reaches a certain point, virtually all of the sample will fail at once. This Step-Stress Program may very possibly prove to be of no value on this device.

#### PROPOSED DEVIATIONS PROGRAM OUTLINE

Due to the results obtained from the completed tests and the testing to date on Shock, Constant Acceleration and the Step-Stress Program, we are drafting a proposal in which the outline and concept of the remaining tests contract will be discussed. This proposal is awaiting more test results. We feel that we have learned a great deal from the work to date. Many of the conclusions, though, are negative. We feel that rather than continue the plan previously outlined, the manpower and devices might be better utilized in tests producing more positive results. Details of this revision have been discussed with a technical representative from Ft. Monmouth and will be included in a proposal to be submitted in March.

TASK 1E - EXHIBIT 1

TYPICAL PHARMACEUTICAL CENTRIFUGE ROTOR



$$\text{RPS} = \sqrt{\frac{G \times 32\text{FT/SEC}^2}{R(\text{FT}) \times 4\pi^2}}$$

$$\text{RPS} = \text{RPM}/60$$

ASSUMING 40,000 RPM

$$R_1 = .1608 \quad G_1 = 86,189.954$$

$$R_2 = .1804 \quad G_2 = 98,939.447$$

$$R_3 = .2001 \quad G_3 = 109,743.843$$

$$R_4 = .2198 \quad G_4 = 120,548.209$$

$$R_3 + R_2 = 10,604.376$$

$$R_4 - R_1 = 32,358.255$$

### **SECTION III**

#### **TASK 2 - PREPARATION OF SUBSTRATE FOR EPITAXIAL GROWTH**

##### **CONTENTS**

##### **PURPOSE**

##### **BACKGROUND**

##### **PROGRESS DURING THIS PERIOD**

Step 1 - Electrolytic Sawing of Silicon

Step 2 - Mechanical - Chemical Polishing

Step 3 - Vapor Etching of Silicon Substrate

##### **PROGRAM FOR NEXT INTERVAL**

EXHIBIT 1 - Sketch, Method of Surface Evaluation

EXHIBIT 2 - Photomicrographs, Comparison of Polishing Techniques

EXHIBIT 3 - Table, Standard Etch Solution

### SECTION III

#### TASK 2 - PREPARATION OF SUBSTRATE FOR EPITAXIAL GROWTH

J. M. Schroeder

##### PURPOSE

The objective of this phase of the program is to determine and implement an improved process for the preparation of substrate for epitaxial growth. The process will have three steps, namely:

1. Sawing of silicon slices by an electrolytic method.
2. Polishing of silicon slices by a mechanical-chemical method to an optical flat surface.
3. Vapor etching of silicon wafers in a closed reactor prior to epitaxial deposition.

##### BACKGROUND

Prior to the work covered by this report the three processes were in various stages of progress:

###### Step 1. Slice Sawing

An investigation of slice sawing and damage inflicted for three types of saws was performed. These saws were the OD, ID, and the reciprocal multi-blade slicer. The information gained from this evaluation indicated that while the multi-blade slicer proved less damaging to the crystal, gross damage was inflicted. Experiments were conducted to determine the feasibility of electrolytic cutting with the multi-blade saw whereby saw damage to the crystal would be virtually eliminated.

###### Step 2. Mechanical-Chemical Polishing

A technique for processing sawed silicon slices to an optically flat, damage free surface was devised through the use of a mechanical-chemical technique. In this process the wafers are placed in a machine,

an acid mixture is added, and after a time cycle deionized water stops the reaction and the slices are removed as optically polished wafers ready for epitaxial deposition. Volume production was limited and mechanical problems inhibited high yield.

### Step 3. Vapor Etching of Silicon Wafers in a Closed Reactor

A method for vapor etching silicon wafers prior to epitaxial deposition was developed. This method removes a pre-determined amount of silicon from the wafer surface in the closed epitaxial reactor. It is believed that foreign material is removed from the surface by the subsequent removal of silicon. The process was well defined in the first report and the process has been under low volume observation since that time.

## PROGRESS DURING THIS PERIOD

### Step 1. Electrolytic Sawing of Silicon

A library search was made for an electrolyte system to be used for this cutting technique. The most promising appears to be ammonium bifluoride, glycerine, and water. Electrode experiments show that a minimum of 14 volts are necessary for cutting and 0.5 amps. per slice are required for a cutting rate of 0.3 inches per hour. Modifications for the multi-blade saw are of a minor nature. An electrical contact brush is required to make contact to the reciprocating blades, the crystal is insulated from the support arm and, likewise, the common negative bias by a ceramic crystal support. A later modification would be to isolate the entire support arm by insulating the bearing mount for this arm from the saw with bakelite. This modification will be postponed until after development work is finished, because the bearings will have to be carefully realigned so the blades will pass through the crystal on the correct plane. Experiments were made with crystal mounting waxes. It was thought that perhaps electrolysis of silicon would be inhibited if the crystal mounting wax interfered with crystal-blade contact. It was found that by mixing a small quantity of powdered graphite with the wax,



electrolysis takes place between wax and blade or perhaps localized heating takes place melting the wax to allow passage of the blade. The graphite also distributes current between slices and an electrode imbedded in the mounting wax. At the present time the following is known of the process:

1. Silicon can be sawed by this method to provide slices with minimum damage compared to those sawed with diamond blades.
2. Fourteen volts at approximately 0.5 amp. per 0.004 inch cut are required.
3. Electrolytic cutting is possible with water as the electrolyte, but serious power supply problems exist.
4. An aqueous additive electrolyte system can be adjusted to allow 14 volts buildup and limit current to 0.5 amps per slice. The multi-blade reciprocating saw is a most advantageous means to adapt anodic corrosion cutting, combining blade (cathode) stability, moving cathode, and enabling 300 cuts to be made simultaneously.

To make this cutting process operational, additional experimentation is necessary in the following areas:

1. Determine ratio of water, glycerine, and ammonium bifluoride for a proper electrolyte system.
2. Determine proper crystal-blade pressures for cutting crystal by anodic corrosion.
3. Determine voltage-current conditions for optimum cutting.
4. Saw a number of crystals for evaluation.

The development of the saw process, as described, has proceeded slowly so that progress could be made on vapor etching and mechanical-chemical polishing, because it would be fruitless to subject a damage-free slice to shaping and polishing techniques that would net a finished substrate

with no improvement over standard material. Because vapor etching and mechanical-chemical polishing have progressed to a "state of the art", further process refinement depends heavily on obtaining a carefully sawed slice. It is believed that development work in the next quarter will realize this objective.

## **Step 2. Mechanical-Chemical Polishing**

Based on the accomplishments of the second quarter of the mechanical-chemical polishing process, a reevaluation or problem survey was made to determine work areas and also find some comparison to gauge progress. A surface study was made with photomicrographs to compare mechanical-chemical with CP6, CP8 and mechanical polished surfaces. The data obtained with magnifications over 100 power were of little significance because it is extremely difficult to focus a microscope on anything other than dust settling from the air on mechanical and mechanical-chemical surfaces, while the characteristic orange peel is obvious on chemically polished surfaces. A surface evaluation method was borrowed from the Research and Development Group whereby a Bausch & Lomb stereo-microscope is used to view the wafer surface. Referring to exhibit one, light diffusing through a sheet of bibulous paper passes through one of the eye pieces, reflects from the wafer surface under study, and is visible through the other eye piece. The magnification most critical to mechanical and mechanical-chemical polished wafers was 10X. Photomicrographs 1, 2, and 3, compare mechanical, mechanical-chemical, and CP6 surfaces by this technique (exhibit two).

A parameter change and effect study was made to determine which of the process variables was most critical. Referring to exhibit three, the etch ingredient most critical was HF concentration. A change of 9% from the normal proved to either slow the reaction or increase the rate to the point that bubble formation caused selective pitting. Surface

velocities were changed from 120 centimeters per minute to 1200 centimeters per minute. A change of this nature definitely effects removal rate, but a compromise between wafer carrier design and surface desired make for optimum conditions at 240 centimeters per minute for the pilot model. Some time was expended to sum up the best parameters and design features in the form of a design for a true production model of this process. The design was completed November 21, 1962, and submitted to the shop for parts fabrication. The machine is presently being assembled. Some of the features incorporated in the design are as follows:

1. Wafers polished on both sides.
2. Automatic magazine loading.
3. Automatic wafer ejection.
4. Continuous process with little operator maintenance.
5. Protection from airborne dust contamination.
6. Capacity of one polished wafer per minute.

This machine will be evaluated in the next quarter and should be in simulated production operation.

### Step 3. Vapor Etching of Silicon Substrate

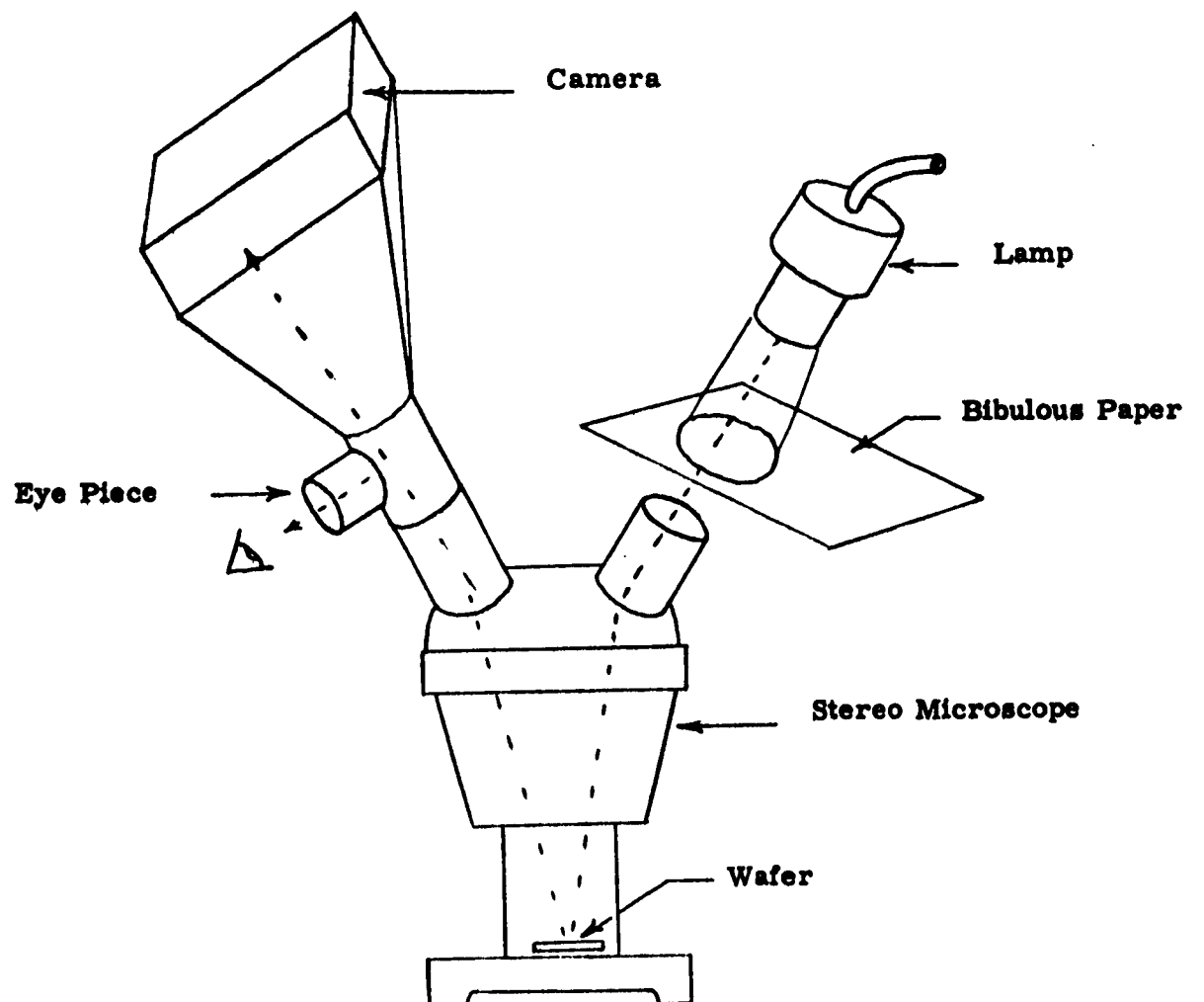
Work in this area was focused on the adaptation of the etch process to an advance design epitaxial reactor. The data from the interim report on vapor etching submitted in the first quarter were used to determine initial non-preferential etch conditions to complement the growth cycle in the new reactor. Only the hydrogen concentration needed changing to lower the etch rate. The rate believed optimum at present appears to be two times growth rate. An evaluation method for the etch process is believed to have been found, in that an opposite type wafer can be vapor etched and grown upon. After mesa etching, these grown junctions may be checked for breakdown characteristics. Evaluations

of this nature would eliminate some of the variables evident in masking and diffusion. The data obtained would be representative of the N on N+ interface even though the diode would be N on P. First evaluations of this type represent marked improvement over non-vapor etched and grown material.

#### PROGRAM FOR NEXT INTERVAL

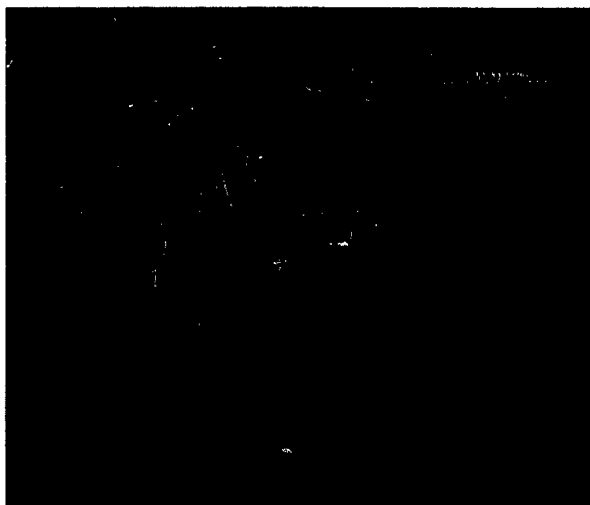
Plans for next quarter include extensive grown junction evaluation relating vapor etching to non-vapor etching, as well as the addition of mechanical-chemical prepared surfaces and electrolytic sawed slices. The production model mechanical chemical polishing will be evaluated with all modifications to be complete by 4-15-63. The electrolytic saw process will be implemented by 4-30-63.

**TASK 2 - EXHIBIT 1**  
**METHOD OF SURFACE EVALUATION**



TASK 2 - EXHIBIT 2

COMPARISON OF POLISHING TECHNIQUES



Photomicrograph No. 1  
Mechanical Polish  
0.5 Micron Diamond  
10X



Photomicrograph No. 2  
Mechanical - Chemical  
10X



Photomicrograph No. 3  
Chemical Polish CP6  
10X

**TASK 2 - EXHIBIT 3**

**MECHANICAL-CHEMICAL POLISHING PROCESS**

**STANDARD ETCH SOLUTION**

<b>NITRIC ACID</b>	<b>4.5 parts by volume</b>
<b>SULFURIC ACID</b>	<b>3.0 parts by volume</b>
<b>HYDROFLUORIC ACID</b>	<b>1.0 parts by volume</b>
<b>ACETIC ACID</b>	<b>2.25 parts by volume</b>

**SECTION III**

**TASK 3 - IMPROVE HEADER PLATING**

**CONTENTS**

**PURPOSE**

**BACKGROUND**

**PROGRESS TO DATE**

**PROGRAM FOR NEXT INTERVAL**



### SECTION III

#### TASK 3 - IMPROVE HEADER PLATING

P. Rollason

##### PURPOSE

This task is directed at providing Fairchild Semiconductor with a gold plated header that is equally suitable for NPN and PNP devices.

The major portion of the time expended on the program during the third quarter was devoted to resolving practical difficulties resulting from the duplex plate development.

##### BACKGROUND

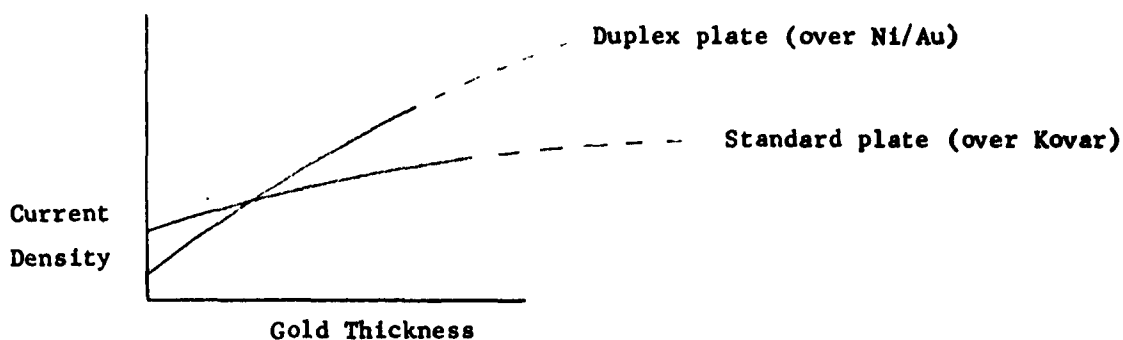
Evaluations #1 and 2 have been performed and reported upon in the second quarterly report. The results, though inconclusive, show that the duplex plate is at least comparable to the standard plate with regard to  $I_{sw}$  ( $150^{\circ}\text{C}$ ) characteristics. The report for the first quarter, page 7, paragraph III, mentioned difficulties encountered in the use of duplex plate, notably variations in thickness and coloration of the plate. Exhibit #7 (test #2 on duplex plating) also indicated that the duplex plated had a greater tendency to discolor after aging for 45 hours in nitrogen at  $300^{\circ}\text{C}$  than did the standard plate.

It was felt that if these difficulties could be overcome that the third evaluation might be expected to show more conclusive results.

##### PROGRESS TO DATE

The essential difference between the standard and duplex plate is that the 24K gold is applied directly to Kovar with the standard plate, while it is applied over a nickel alloyed plate in the case of duplex. Since variations in thickness on the headers plated in any one plating batch were greater with the duplex plate it seemed that the 24K gold was being applied more efficiently, i.e. the gold deposition rate was more closely proportional to the current density than in the case of the standard plate.

The following graph summarizes the relationship between current density and rate of deposition on the standard and duplex plates.



The observations resulting in the curves shown are substantiated by the hydrogen overvoltage potentials on the two plating substrates.

<u>Metal Substrate</u>	<u>Hydrogen overvoltage</u>
Iron	1.29*
Gold	0.80*
Iron	0.116**
Gold	0.045**

If we consider iron as similar to Kovar, then it seems that the deposition rate of gold on gold is influenced less by hydrogen overvoltage and thus tends to be more directly proportional to the current density.

Summarizing the foregoing, it seemed that variations in thickness with the duplex plate were inherent with the plating barrel geometry and plating bath then in use.

The most reasonable solution seemed to be to make up a gold bath having the desired characteristics. Other advantages which would result from this decision would be lower cost and greater control over the composition of the bath compared to the proprietary bath presently in use.

It was determined that the optimum gold bath should have:

1. A simple organic salt buffering system.
2. High specific gravity.
3. Low gold concentration.

\* Modern Electroplating, A. G. Gray, p. 577

\*\* Electrochemistry, E. C. Potter, p. 135

The gold bath prepared used a potassium citrate/citric acid solution adjusted to 16 - 18° Baumé and the gold concentration was maintained at 0.3 - 0.4 troy ozs per gallon.

Several trial and error runs were plated to determine the optimum plating conditions in the new bath. When these were found, the process was frozen and used in limited production for two months. At this date the bath is plating satisfactorily, indicating that it is not overly susceptible to contamination and that it has a life-time sufficiently long to make it an economical production item.

Examination of headers plated by this process compared to headers plated with the proprietary gold bath gave rise to the following comparisons:

	<u>Fairchild Gold</u>	<u>Proprietary Gold</u>
Color	uniform yellow	varies from yellow to brown
Structure	uniform fine grain	coarse on brown units ±30%
Thickness	± 10% variation	variation

The process which will be used in plating headers for evaluations #3 and 4 is as follows:

Batch size	4000 TO 5 headers
Barrel size	10" x 12" polypropylene, solid cathode rod

Procedure:

	<u>Immersion time</u>
Descale solution	3, -0 + 1 mins
Tap water rinse	1, -0 + 1 mins
Alkaline soak clean	2, -0 + 1 mins
Tap water rinse	1, -0 + 1 mins
Deionized water rinse	1, -0 + 1 mins
Deionized water rinse	2, -0 + 1 mins
Wilbro 264N acid gold	20(± 10 sec) mins at 10 amperes
Deionized water rinse	1, -0 + 1 mins

Procedure:

Immersion time

Deionized water rinse	1, -0 +1 mins
Fairchild gold bath	20 ( $\pm$ 10 sec) mins at 12 amperes
Drag out rinse	1/2 ( $\pm$ 10 secs) mins
Deionized water rinse	2, -0 + mins
Deionized water rinse	5, -0 + 2 mins
Isopropyl alcohol	1/2 ( $\pm$ 10 secs) mins
Hot air dry	5 mins or until dry

PROGRAM FOR NEXT INTERVAL

Headers will be plated and submitted for evaluation #3 and 4. If the evaluations show Isw (150°C) and general plating characteristics superior to those obtainable using the standard process, then it is expected that complete process specifications will be written and final evaluations will be made.

**SECTION III**

**TASK 4 - ISOLATE AND ELIMINATE SOURCES OF GROSS PARTICLES**

**CONTENTS**

**PURPOSE**

**PROGRESS**

**PREVENTING CREATION OF PARTICLES**

**KEEP EXISTING PARTICLES AWAY FROM UNWELDED TRANSISTORS**

**PARTICLE DETECTION**

**PROGRAM FOR NEXT INTERVAL**

### SECTION III

#### TASK 4 - ISOLATE AND ELIMINATE SOURCES OF GROSS PARTICLES

P. M. Weiler

##### PURPOSE

The purpose of this task is to 1) prevent particles which are detrimental to the operation of a transistor from getting into otherwise good transistors; and 2) detect particles which do get into transistors. The critical process step in keeping particles out of transistors is the final seal operation. We are attempting to eliminate particles in finished units at this station by:

1. Preventing creation of particles
2. Keeping existing particles away from uncapped transistors
3. Detecting particles in finished units.

##### PROGRESS

Preventing creation of particles:

1. Weld Schedule - work finished and report written in first quarterly report.
2. Electrode Finish - work finished and comments in second quarterly report.
3. Electrode Material - we recently changed our electrode material (for economic means) for Elkonite 20W3 to Mallory 100.

The Mallory 100 has about the same hardness as the Elkonite, but better conductivity. This has resulted in longer life for electrodes and better welds. It also appears to generate less splash although this is more of an opinion than a fact because of the difficulty in measuring splash. However, from the experience of the writer with final seal welders, it definitely appeared that Mallory 100 gave less splash than our older material. This is probably the result of our being able to use less current for the same good welds and, thus, less heat is generated in the electrodes, between the electrodes and the parts, and in the header and can. The only location of high heat is concentrated at the can-header interface where the weld will occur.

This reduction in splash was probably also helped when we changed to the new material by our reducing the current and increasing the weld cycle. Thus, the heat was applied in a more gradual manner and most gas pockets in the material being melted would release gradually instead of explosively. The explosive release causes splash.

This change in electrode material was not originally proposed for this contract, but is being mentioned in this report because of the unforeseen help it appears to be giving on the control of weld splash.

Keep existing particles away from unwelded transistors:

1. Lead Guide Cones - The purpose for these is to form a shield around the final seal electrodes and prevent any splash from getting to uncovered electrodes. This project has had no work done pending a new configuration of electrodes, and the belief that the can preassembly project will give better results.
2. New Plexiglas Dryboxes - The purposes of the new plexiglas dryboxes are:
  - a) prevent any particles outside the drybox from entering into the unfinished transistor area.
  - b) provide shielding inside the drybox for uncapped transistors,
  - c) provide better visibility of the inside of the drybox and better reveal the cleanliness, or dirtiness of the drybox,
  - d) provide an easily cleaned drybox,
  - e) eliminate as far as possible any metal parts in the drybox which might produce metallic particles, and
  - f) provide a neat looking drybox which will provide a psychological desire to keep it clean.

The last quarterly report went into detail about the advantages and workings of the new drybox (with pictures) and should be referred to for further information. By the next quarterly report we will have plexiglass dryboxes on our 2N914 and 2N995 lines and the project will be completed.

3. Cleaning Procedure - The new procedure has been in force on plexiglas dryboxes since June. The procedure is proving adequate and will be included on new dryboxes as they are installed.
4. Pre-assembly of Cans - This project appears very promising and we feel it will prove one of the best means of keeping particles away from transistors. The purpose of the preassembly procedure is to place cans onto transistor headers as they enter the drybox from the vacuum bake of the nitrogen drying chamber, and thus have the transistor protected from particles by a covering can. The can will protect the transistor from any weld splash, or other particles that might be directed toward the transistor. The can will not be removed and will become a permanent part of the transistor at final seal. A more detailed explanation of the process is included in the second quarterly report.

To date, we have a prototype jig built and debugged. The project is back in design for the final formal prints. Approval has been given by management for the installation of this project and when the drawings are finished, the parts will be ordered. By the next quarterly report, can preassembly should be about ready to install if not already installed, depending on delivery of parts and debugging.

Particle Detection - Although we believe the above projects will help to achieve the goal of eliminating particles in transistors, we still needed a tool to find if there are any particles in transistors. To make a check for the presence of particles in finished transistors, we have tried testing with a high frequency amplifier. We have tried using the amplifier by having the operator place transistors in the microphone and then shake the microphone and listen for the rattle of a particle inside. Although it proved somewhat effective, this method was slow and many times inaccurate because of the background noise caused by the transistor movement on the microphone. A vibrator jig was built, but this produced an even greater amount of background noise. We have recently come up with a new spring jig which appears very effective. The jig comprises a



transducer microphone mounted firmly on a vertically mounted leaf spring. On the top of the microphone is mounted a clamp to hold an upside down transistor against a microphone transducer. The operator places a transistor upside down in the clamp which presses it firmly against the microphone transducer. The operator then flips the spring which vibrates and in turn vibrates the microphone with the transistor firmly held against the microphone. Thus, everything on the jig, the spring, the microphone and the transistor move as one solid unit and will set up no background noise. The only possible part that could move freely would be a loose particle in the can of the transistor. If there is a particle, the vibration of the jig will cause the particle to roll, slide, or bounce inside the can and, thus, set up weak high frequency sound. Because of the firm immediate contact of the can to the microphone transducer, the rolling, sliding or bouncing sound is picked up, amplified and reduced in frequency to the audible range. The amplifier will then broadcast the rolling, sliding or bouncing noise through a speaker and when the operator hears this noise she knows there is a particle inside the transistor.

In order to evaluate the above system, we purposely welded particles into some blank units. We enclosed one mil. gold wire particles (average weight = .3 mlg) in 25 TO-5 headers, and enclosed various materials as preforms, dice, etc., in five units. We also clipped about 1/4 inch off one lead of each to identify the units. We then performed the following experiment.

1. A technician was told that we suspect the presence of particles in a sample of 300 good units. She checked all the units on the particle detector and no defective units were found.
2. The technician was given 100 units out of which five contained the miscellaneous particles mentioned above. She identified all five defectives on the first pass.
3. The technician was given a sample of 100 units of which 25 contained the one mil. wires. The technician correctly identified 19 of the defective units, and made no mistakes on the good units. The six defective units

that were missed probably had the wires caught in the crack between the side of the can and the side of the header, and, thus, not loose to roll, slide or bounce.

The particle detector appears to be fairly effective, although not perfect. The only particles not detectable were probably caught in the crack between the header and the can, and these particles probably would not be found by any other means either. A possible solution would be to test all units immediately after centrifuge or similar station where all particles would most likely be dislodged from the crack.

As has been mentioned, the new spring jig for the acoustical tester appears as a very good solution, and is almost ready for use. We have sent the jig back to design for refinements to make it work a little more smoothly, but the jig should be fully operational by the next quarterly report.

#### PROGRAM FOR NEXT INTERVAL

Complete installation of all equipment described above.

**SECTION III**

**TASK 5 - PREFORM ELIMINATION**

**CONTENTS**

**ABSTRACT**

**NARRATIVE AND DATA**

**CONCLUSIONS**

**PROGRAM FOR NEXT INTERVAL**

**EXHIBIT 1 - EQUIPMENT**

**EXHIBIT 2 - ELECTRICAL TEST CONDITIONS**

**EXHIBIT 3 - PARAMETER FREQUENCY DISTRIBUTIONS ( 12 sheets)**

**EXHIBIT 4 -  $\bar{X}$  AND R CHARTS ( 8 sheets)**

**EXHIBIT 5 - TABLE 1, STORAGE LIFE TEST DATA**

**TABLE 2, OPERATING LIFE TEST DATA**

SECTION III  
TASK 5 - PREFORM ELIMINATION

G. E. Davis

ABSTRACT

Available data on 2N914 and 2N995 devices continue to indicate that these devices can be assembled with vacuum evaporated preform material.

NARRATIVE AND DATA

The time period covered by this report was devoted entirely to testing the devices assembled during the period covered by the first quarterly report. The test units were assembled by vacuum evaporating preform material onto the backsides of wafers prior to the dicing operation. No separate preform was used during the die-attach operation. The control units were drawn from finished stores. These units were assembled with separate preforms. The preform material was 99.7 percent gold and 0.3 percent antimony for 2N914 devices and 99.3 percent gold and 0.7 percent boron for 2N995 devices. A description of the equipment and procedure used may be found in the Task 5 section of the first quarterly report.

Different evaluation procedures were used for each type of device. In the case of 2N914 devices, statistical tests were carried out with the use of a computer. The results of these tests will be discussed later in this report. 2N995 data were evaluated graphically. Statistical tests were used only when the graphic representation failed to determine a difference between test and control units clearly. A series of frequency distribution charts may be found in exhibit 3. These charts compare test units to control units in each test (operating life and storage life) and each time point (0, 250 and 500 hours). Only two electrical parameters,  $V_{BE}$  (sat) and  $V_{CE}$  (sat), are illustrated in the charts. The third parameter tested,  $I_{SW}$ , is a go-no-go test. There were no  $I_{SW}$  failures in any test or control group. This is true for both 2N914 and 2N995 devices.

Except for 0 hour storage life test  $V_{CE}$  (sat), 0 hour storage life test  $V_{BE}$  (sat), 250 hour operating life test  $V_{BE}$  (sat) and 500 hour operating life test  $V_{BE}$  (sat), the

frequency charts indicate no significant difference between test and control groups. Standard "F" and "t" tests were performed on the above mentioned test data. The results of these tests are tabulated below:

Test	Significant Difference in Variance (F test)?	Significant Difference in Mean (t test) ?
0 hour storage life test $V_{CE}$ (sat)	No	Yes - 99.5% significant
0 hour storage life test $V_{BE}$ (sat)	No	Yes - 99.5% significant
250 hour operating life test $V_{BE}$ (sat)	No	No
500 hour operating life test $V_{BE}$ (sat)	No	Yes - 99.5% significant

In all three cases where a significant difference in mean is indicated the test units exhibited the higher value of the parameter involved. It is desired that both  $V_{BE}$  (sat) and  $V_{CE}$  (sat) values be minima. Although the test units did show higher values for these parameters than did the control units, in no case did any test unit fail to be accepted as a good unit. The acceptance limit for  $V_{BE}$  (sat) is 0.90 volt and for  $V_{CE}$  (sat) is 0.30 volt. In both cases the value given is the maximum acceptable value.

A series of  $\bar{X}$  and R charts may be found in exhibit 4. The purpose of these charts is to illustrate the effect of storage life and operating life testing on a particular group of devices. The charts were constructed by the following method:

1. The data were recorded in groups of five units.
2. The mean and range were calculated for each group of five.
3. The grand average  $\bar{\bar{X}}$  and range R (indicated by solid horizontal lines) were calculated.
4. The data were plotted on the charts. The order of plotting was the same as the order in which the values were recorded by the Datalogger.
5. The charts were divided by vertical broken lines at the divisions between 0 hour, 250 hour, and 500 hour data.

6. The control limits (indicated by horizontal broken lines) were calculated by the methods described in the Western Electric "Statistical Quality Control Handbook".

In general, the charts indicate that storage life and operating life testing had little or no effect on the values of  $V_{BE}$  (sat) and  $V_{CE}$  (sat). Inspection of the charts will show that several points fell outside of the control limits. In the cases where these points are marked with X's, the apparent loss of control can be explained as a measuring equipment error. As an example, consider the first point marked with an X on the  $\bar{X}$  chart for  $V_{CE}$  (sat) of the storage life test units. The particular unit involved is unit number 8431. At 0 hours the recorded value of  $V_{CE}$  (sat) for this unit was 0.22 volt, at 250 hours it was 0.01 volt and at 500 hours it was 0.22 volt again. Obviously the 250 hour value is erroneous. Similar occurrences account for all points marked with X's. No explanation can be offered for those points outside of the control units which are not marked with X's.

In the case of 2N914 devices, statistical tests were carried out on an IBM 1620 computer. "F" and "t" tests were conducted for 24 different comparisons. The results of these test are listed in Tables I and II in exhibit 5. The symbols used in the tables are as follows.

A = test group

B = control group

TP1 = 0 hour

TP2 = 250 hours

$N_x$  = number of units in the group mentioned first in the "comparison" column.

$N_y$  = number of units in the group mentioned last in the "comparison" column.

df = degrees of freedom

$S_t$  = significance level of t

$S_f$  = significance level of F

Referring to the group mentioned first in the "comparison" column as x and the

group mentioned last as y the tables may be interpreted as follows:

"t" test: If the value of t is positive, the mean of x tends to be higher than the mean of y. If the t is negative, the opposite is true. The  $S_t$  column given the probability that the means of x and y are significantly different. If the word "no" appears in the  $S_t$  column there is no significant difference between the means.

"F" test: If the F value is given in the F (x/y) column, the variance of x tends to be greater than the variance of y. If the F value appears in the F (y/x) column, the opposite is true. The  $S_F$  column given the probability that the variances of x and y are significantly different. If the word "no" appears in the  $S_F$  column there is no significant difference between the variances.

These test indicate that, in general, the test units have lower  $V_{CE}$  (sat) and  $V_{BE}$  (sat) values than the control units. They also indicate that the test groups have tighter distributions than the control units. A third indication is that aging tends to reduce the mean values and increase the variances of both the test and control groups.

#### CONCLUSIONS

Data obtained to date continue to indicate the feasibility of eliminating separate preforms in the assembly of 2N914 and 2N995 devices. In the case of 2N914 devices, elimination of separate preforms actually makes superior units in-so-far as the tested parameters are concerned. In the case of 2N995 devices, there is no increase in quality, but neither is there a significant decrease in quality.

#### PROGRAM FOR NEXT INTERVAL

The testing program described in the first quarterly report shall be continued through 1000 hours of aging. In addition, a second test of 2N914 devices has been initiated. These devices shall be assembled and tested in a manner similar to the original testing program. A similar test of 2N995 devices shall also be initiated.

## TASK 5 - EXHIBIT 1

### EQUIPMENT

1. Life Test Parameter Test Equipment: Fairchild Datalogger, fabricated by Instrumentation Department, Fairchild Semiconductor.
2. Computer: IBM 1620 computer, manufactured by International Business Machines.

## TASK 5 - EXHIBIT 2

### ELECTRICAL TEST CONDITIONS

#### 1. 2N914

- a.  $V_{BE}$  (sat):  $I_C = 10 \text{ ma}$ ,  $I_B = 1 \text{ ma}$
- b.  $V_{CE}$  (sat):
  - 1)  $I_C = 10 \text{ ma}$ ,  $I_B = 1 \text{ ma}$
  - 2)  $I_C = 200 \text{ ma}$ ,  $I_B = 20 \text{ ma}$

#### 2. 2N995

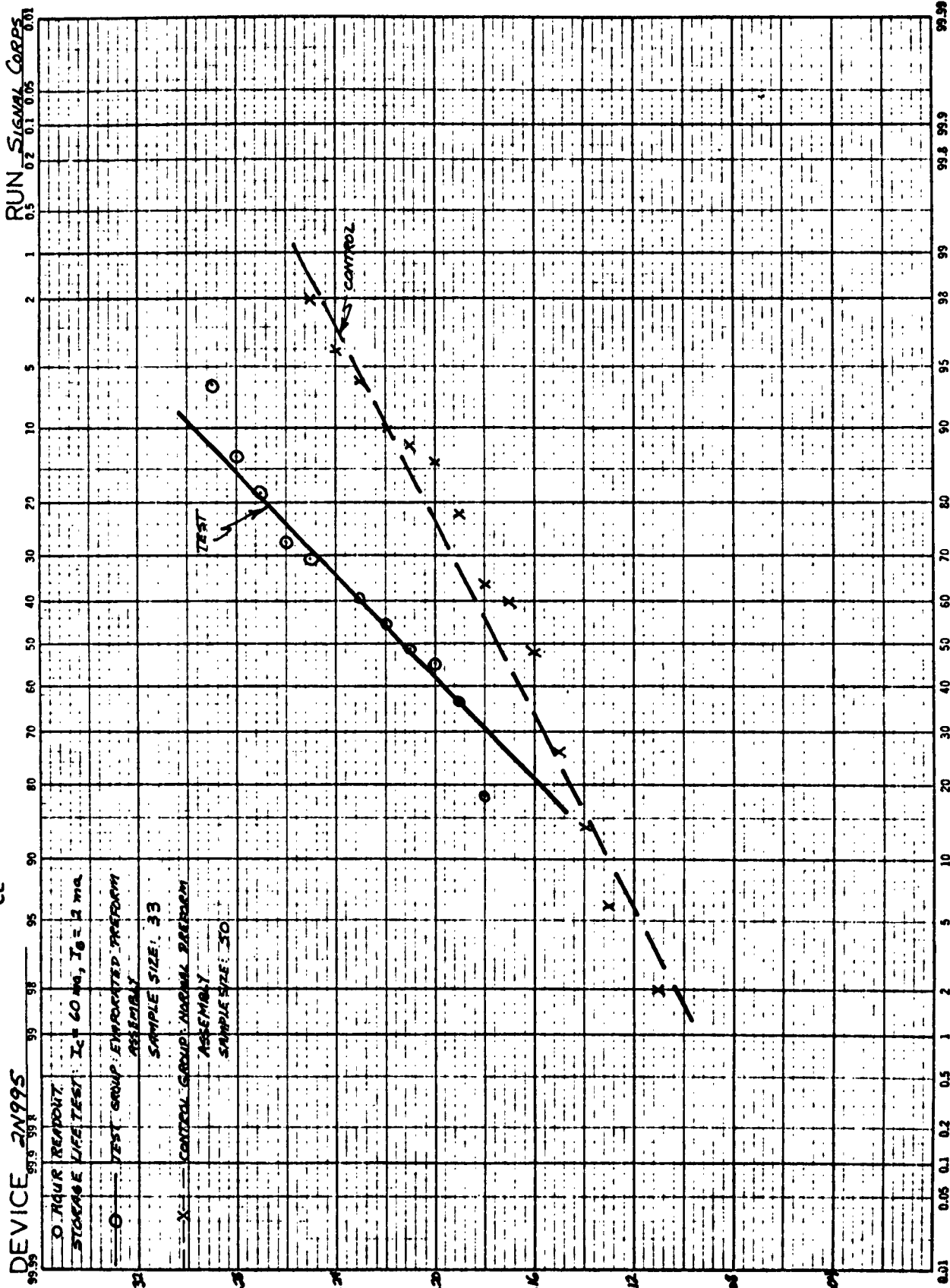
- a.  $V_{BE}$  (sat):  $I_C = 60 \text{ ma}$ ,  $I_B = 2 \text{ ma}$
- b.  $V_{CE}$  (sat):  $I_C = 60 \text{ ma}$ ,  $I_B = 2 \text{ ma}$



K-2 PROBABILITY SCALE 359-23  
X 90 DIVISIONS  
KEUFFEL & ESSER CO. MADE IN U.S.A.

EXPERIMENT PREFORM ELIMINATION

$V_{CE}$  (sat.) vs FREQUENCY DISTRIBUTION



$V_{CE}$  (sat.), volts

III - 5 - 7

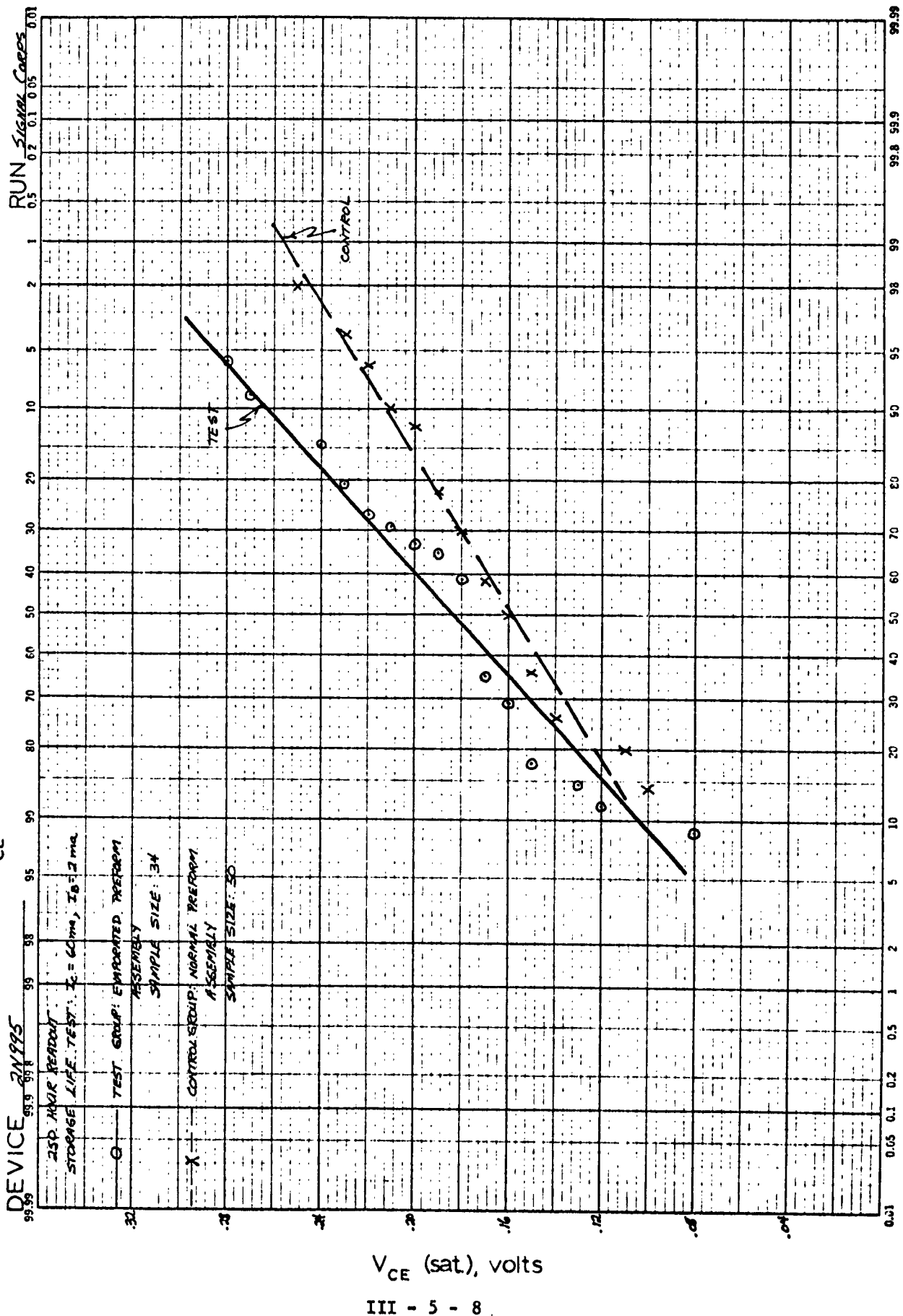
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TASK 5 - EXHIBIT 3

2/4/63 END

K $\Sigma$  PROBABILITY SCALE 359-23  
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KEUFFEL & ESSER CO. MADE IN U.S.A.

# EXPERIMENT PREFORM ELIMINATION V<sub>CE</sub> (sat.) vs FREQUENCY DISTRIBUTION



% UNITS < ORDINATE

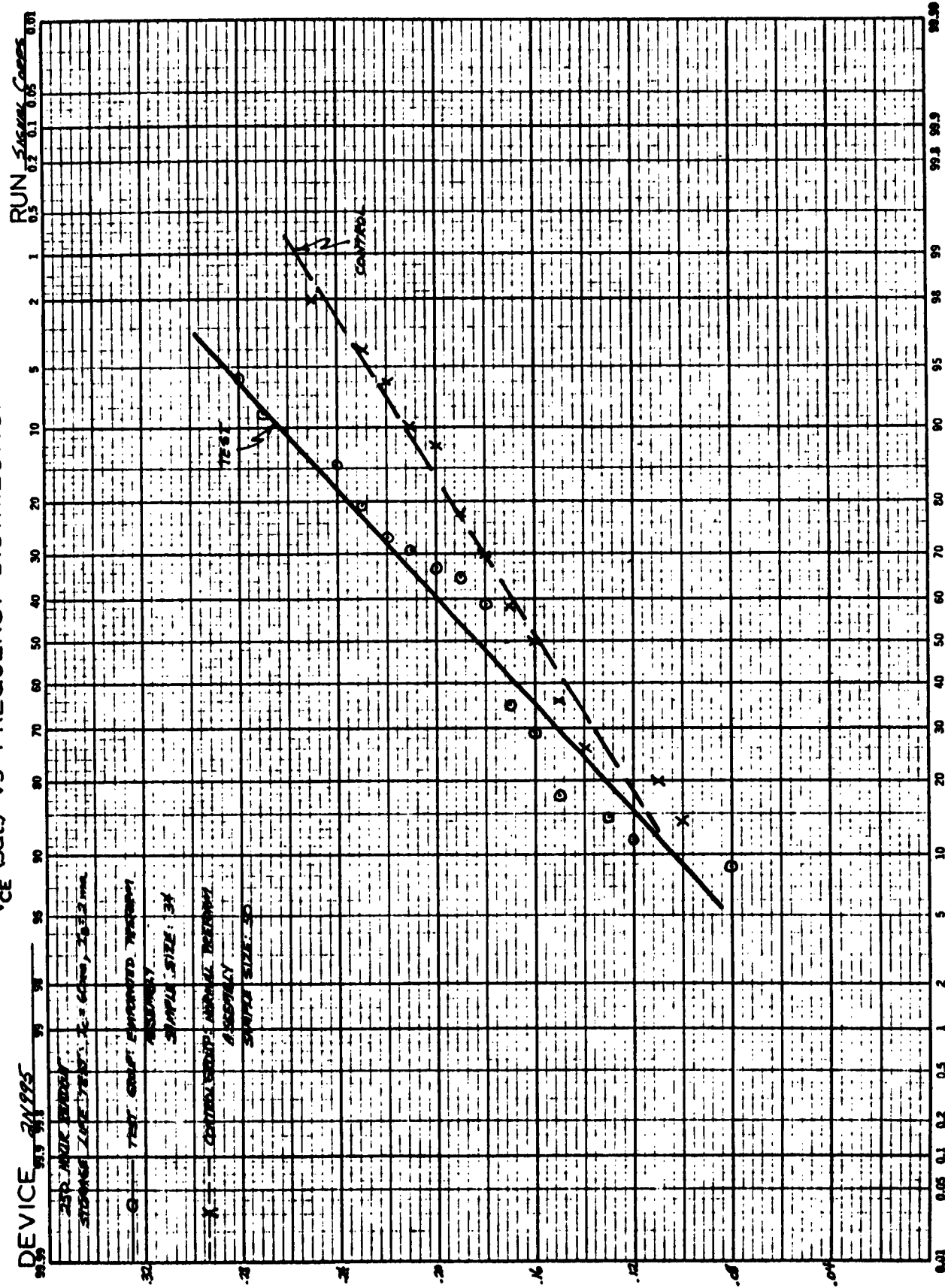
TASK 5 - EXHIBIT 3

2/4/63 ccd

KOE PROBABILITY SCALE 359-23  
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EXPERIMENT DESIGNATION

$V_{CE}$  (sat) vs FREQUENCY DISTRIBUTION

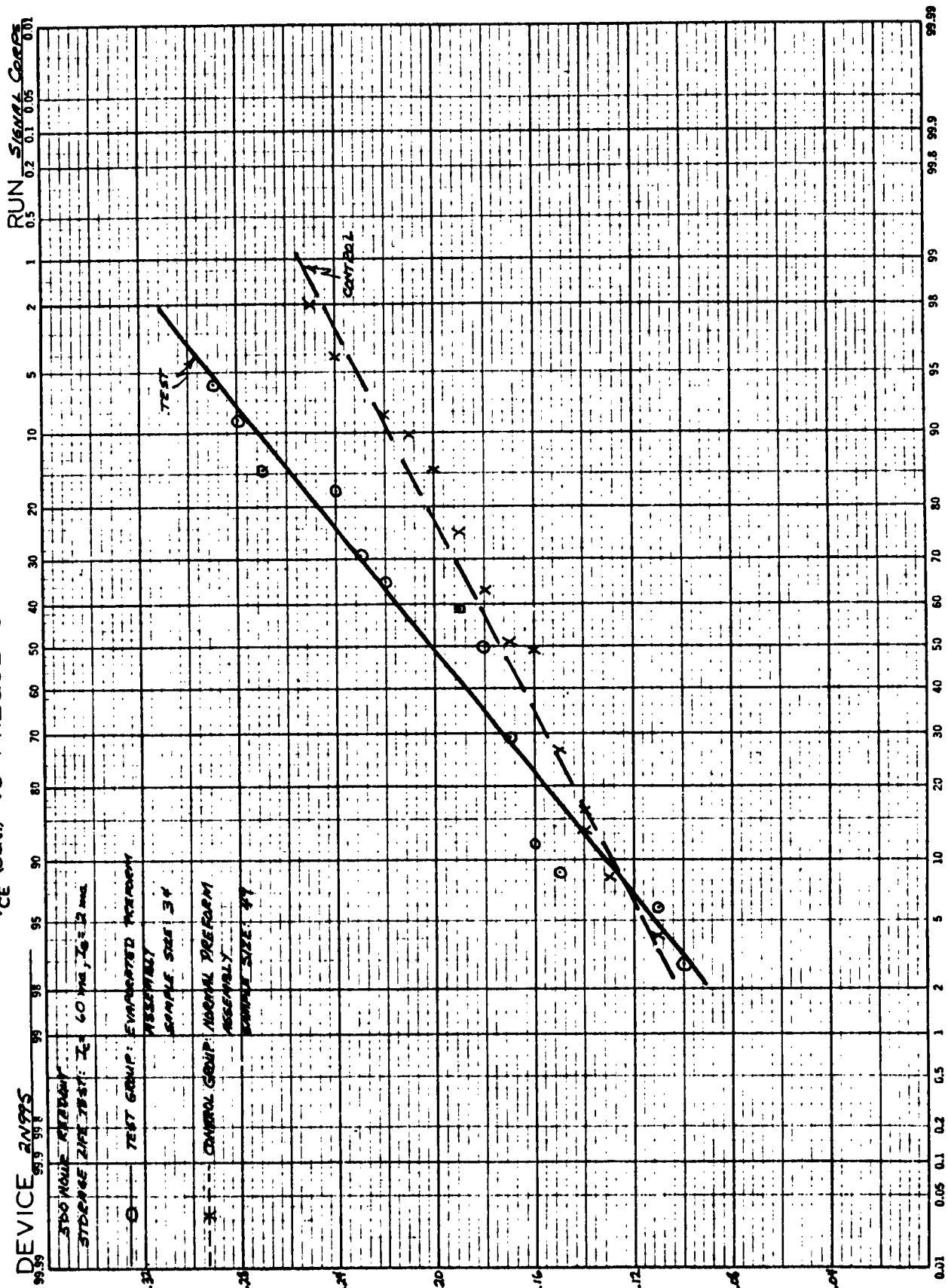


$V_{CE}$  (sat), volts

K $\sigma$ E PROBABILITY SCALE 359-23  
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MADE IN U.S.A.

# EXPERIMENT PREFORM ELIMINATION

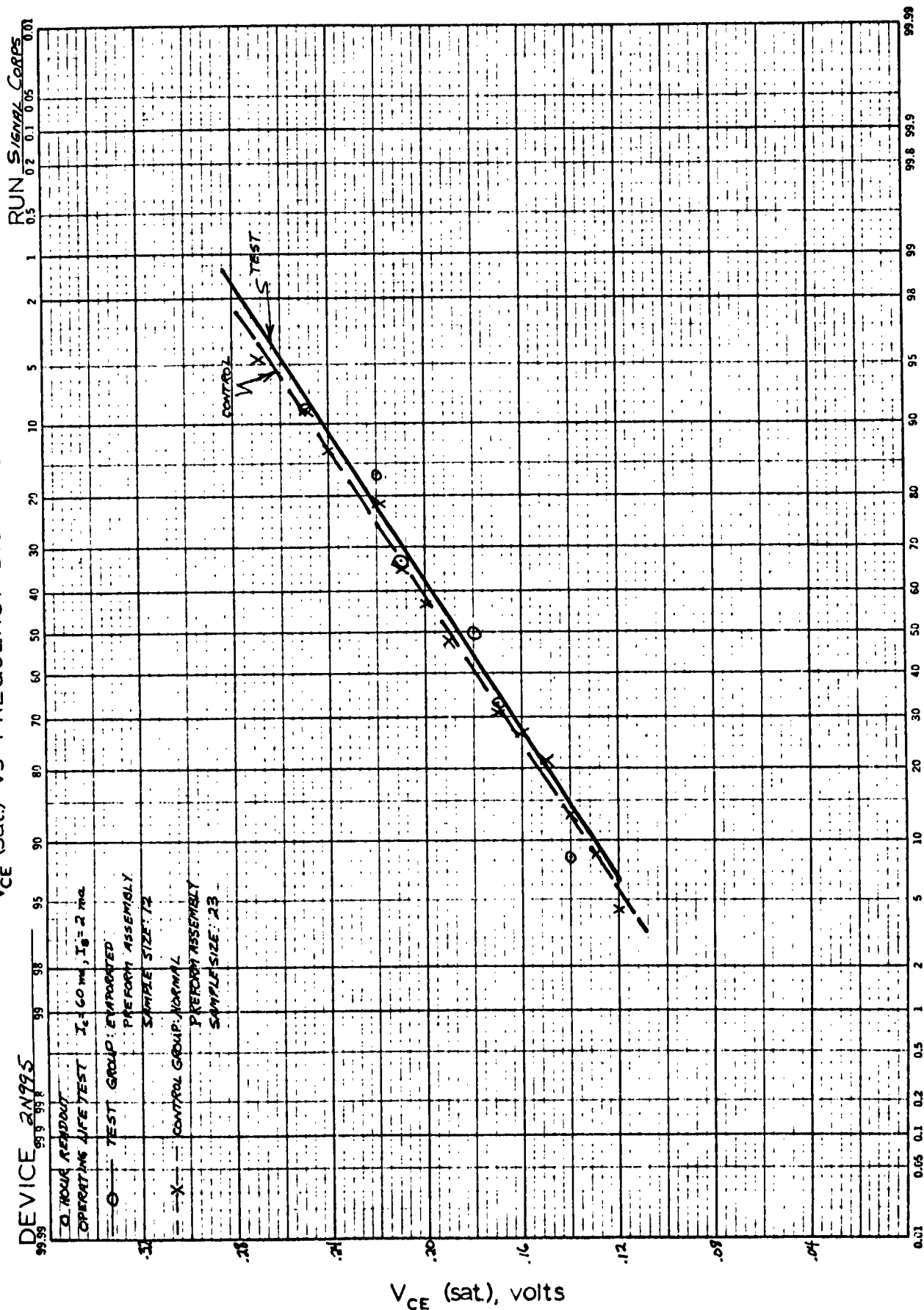
$V_{CE}$  (sat.) vs FREQUENCY DISTRIBUTION



$V_{CE}$  (sat.), volts  
III - 5 - 9

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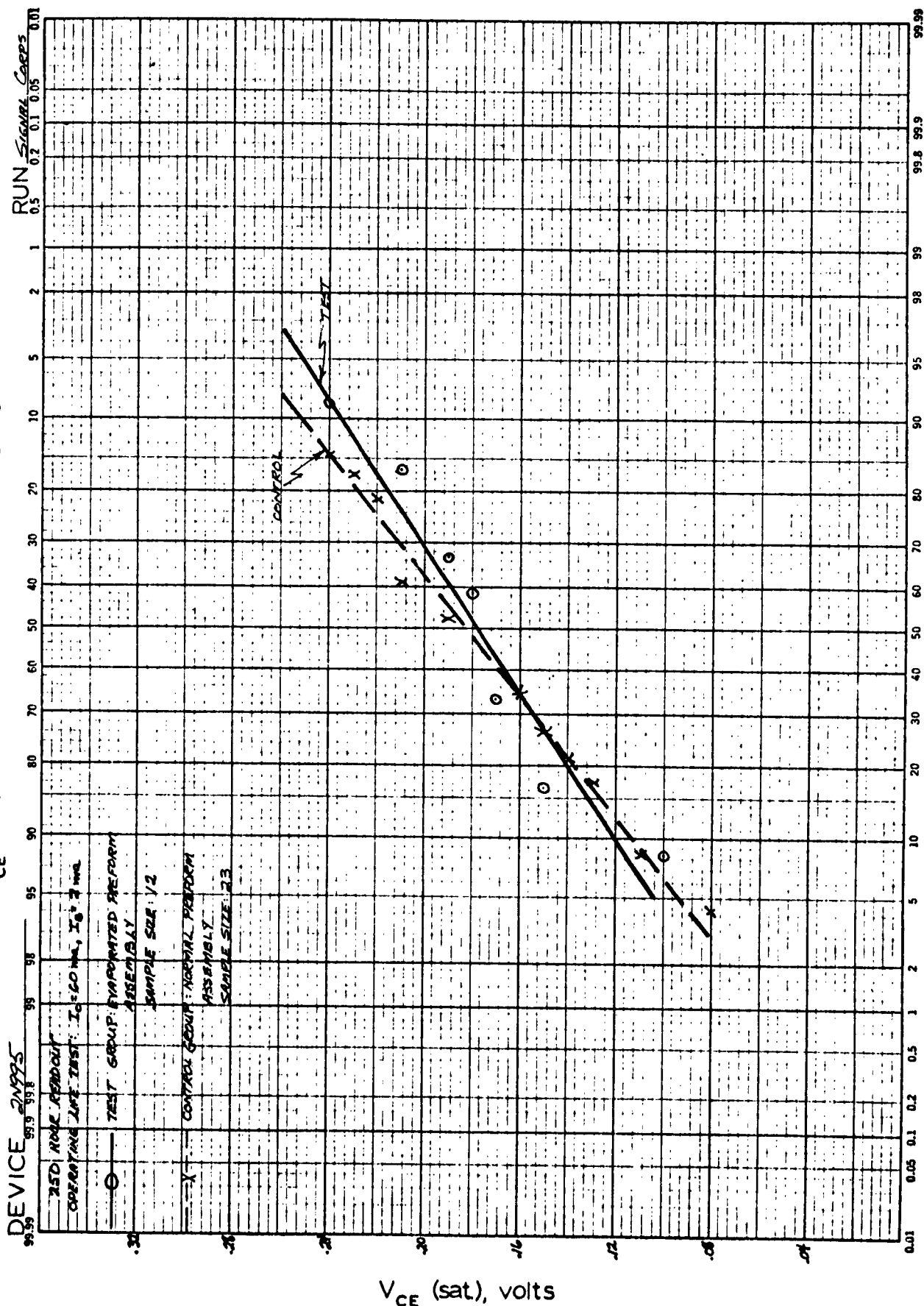
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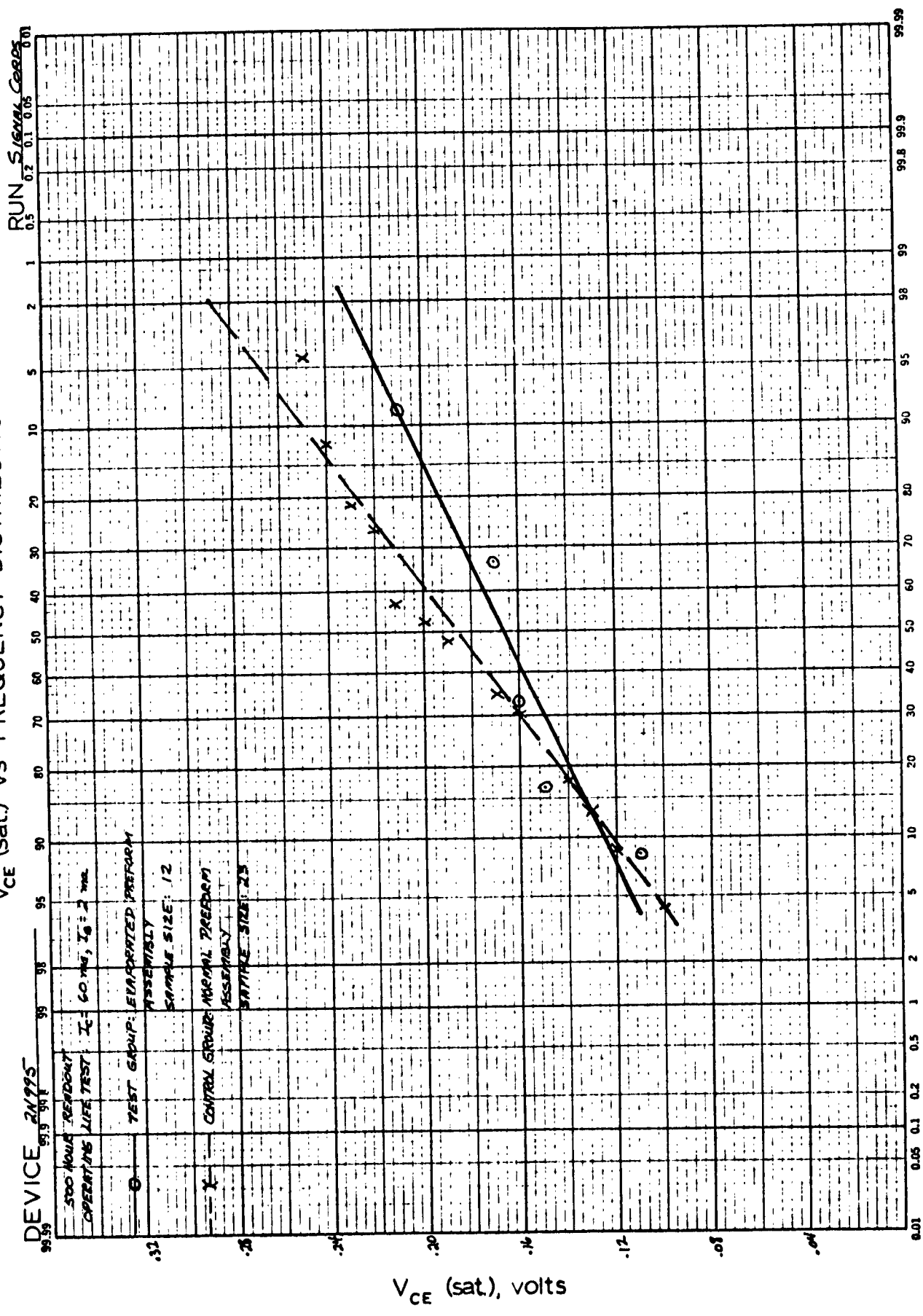
# EXPERIMENT FREEDOM ELIMINATION

$V_{CE}$  (sat.) vs FREQUENCY DISTRIBUTION



KOE PROBABILITY SCALE 359-23  
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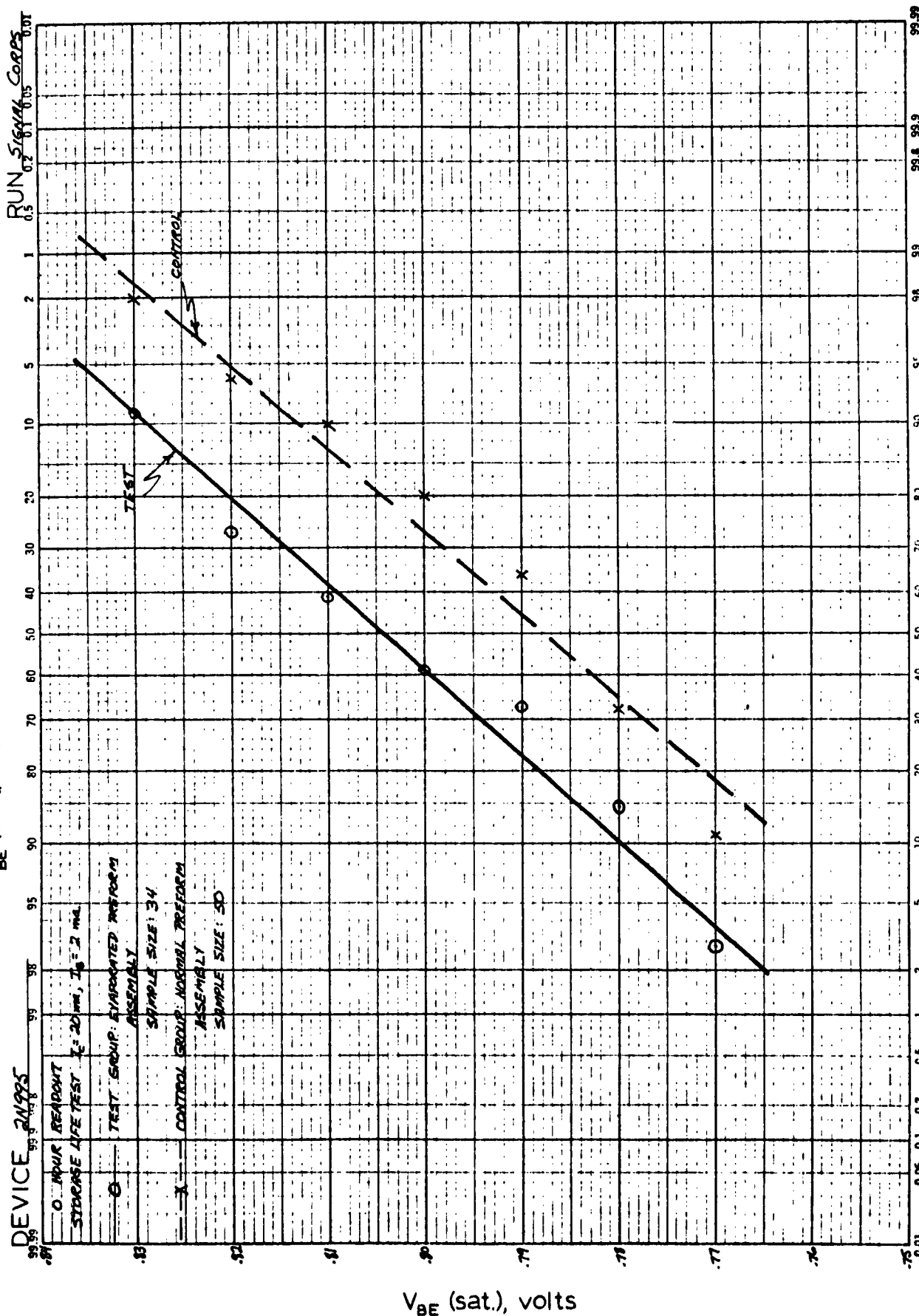
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# EXPERIMENT: PREFORM ELIMINATION

$V_{BE}$  (sat.) vs FREQUENCY DISTRIBUTION

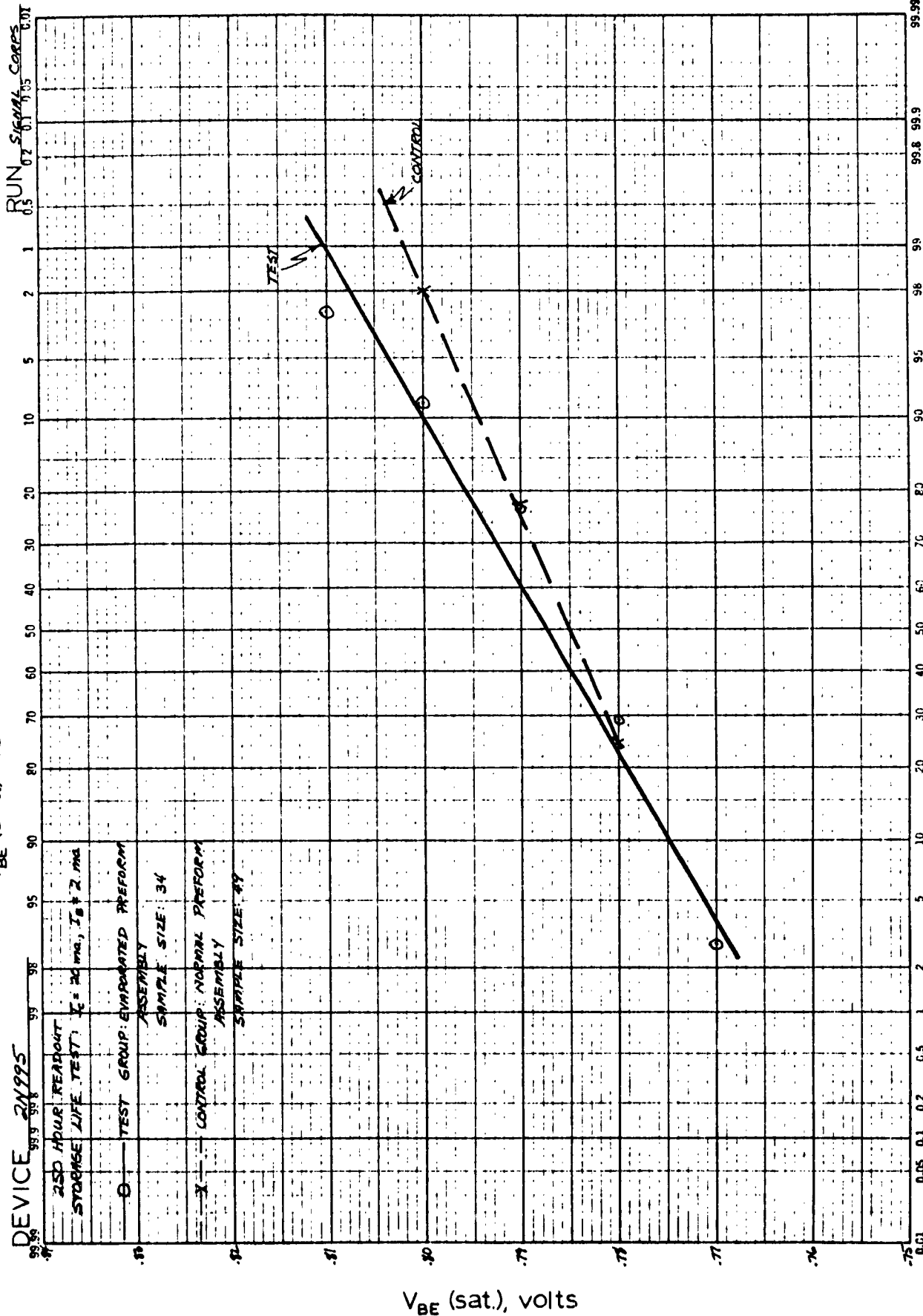




K-Σ PROBABILITY SCALE 359-23  
K-90 DIVISIONS  
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EXPERIMENT PREFORM ELIMINATION

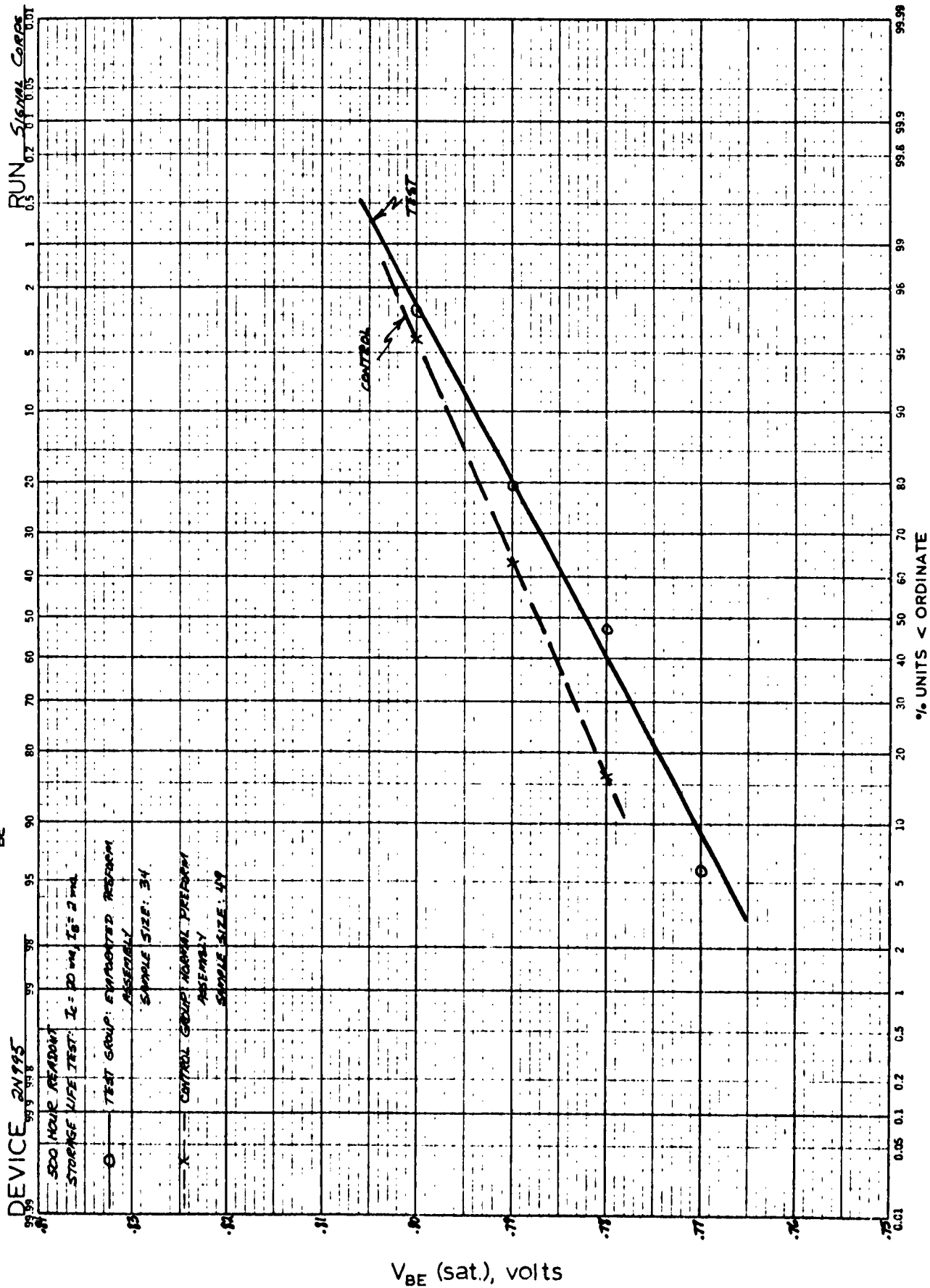
$V_{BE}$  (sat) vs FREQUENCY DISTRIBUTION



K-2 PROBABILITY SCALE 359-23  
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# EXPERIMENT PREFORM ELIMINATION

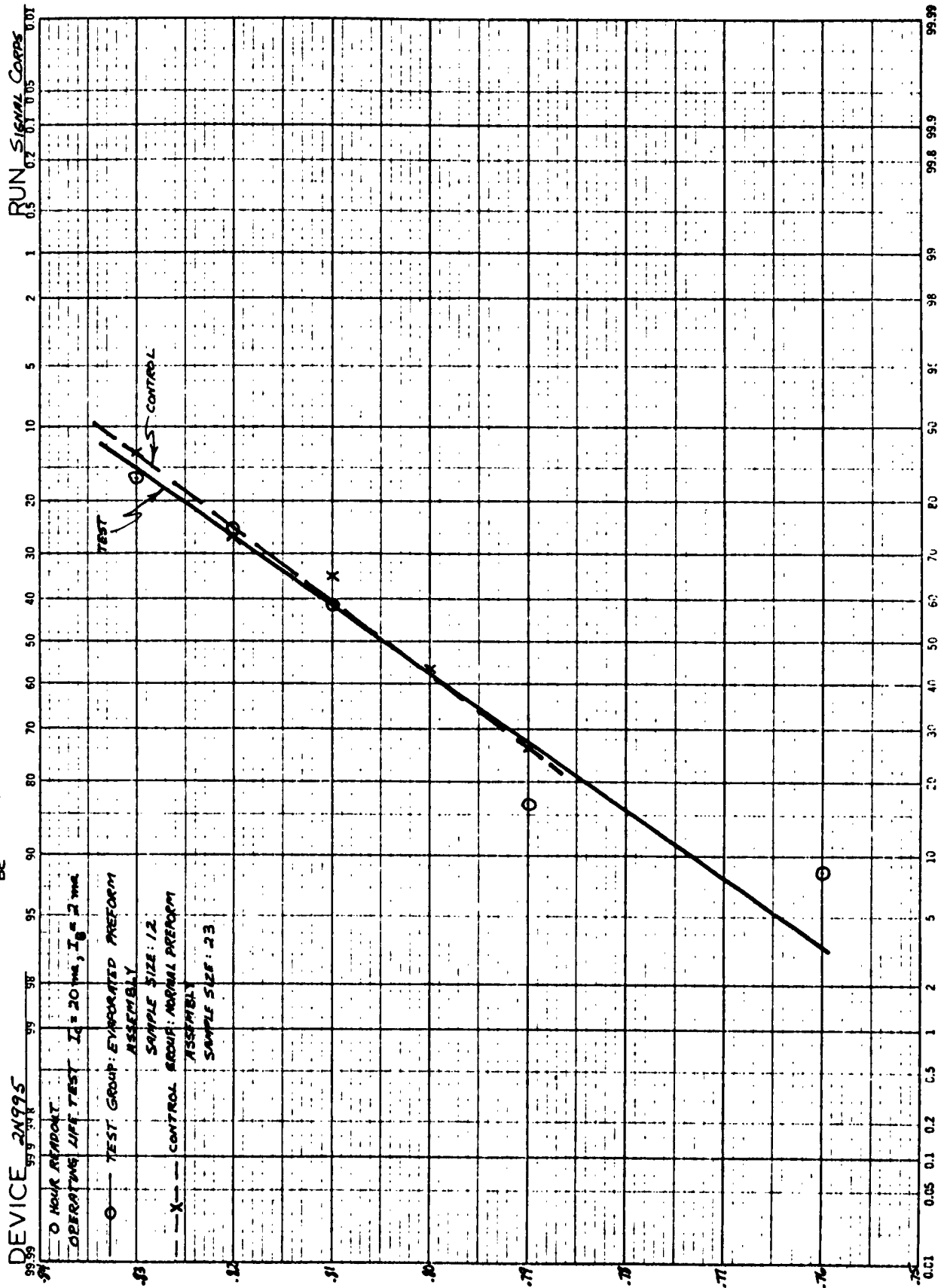
$V_{BE}$  (sat.) vs FREQUENCY DISTRIBUTION



K<sub>0</sub>Σ PROBABILITY SCALE 359-23  
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KEUFFEL & ESSER CO. BRIDGEVILLE, PA.

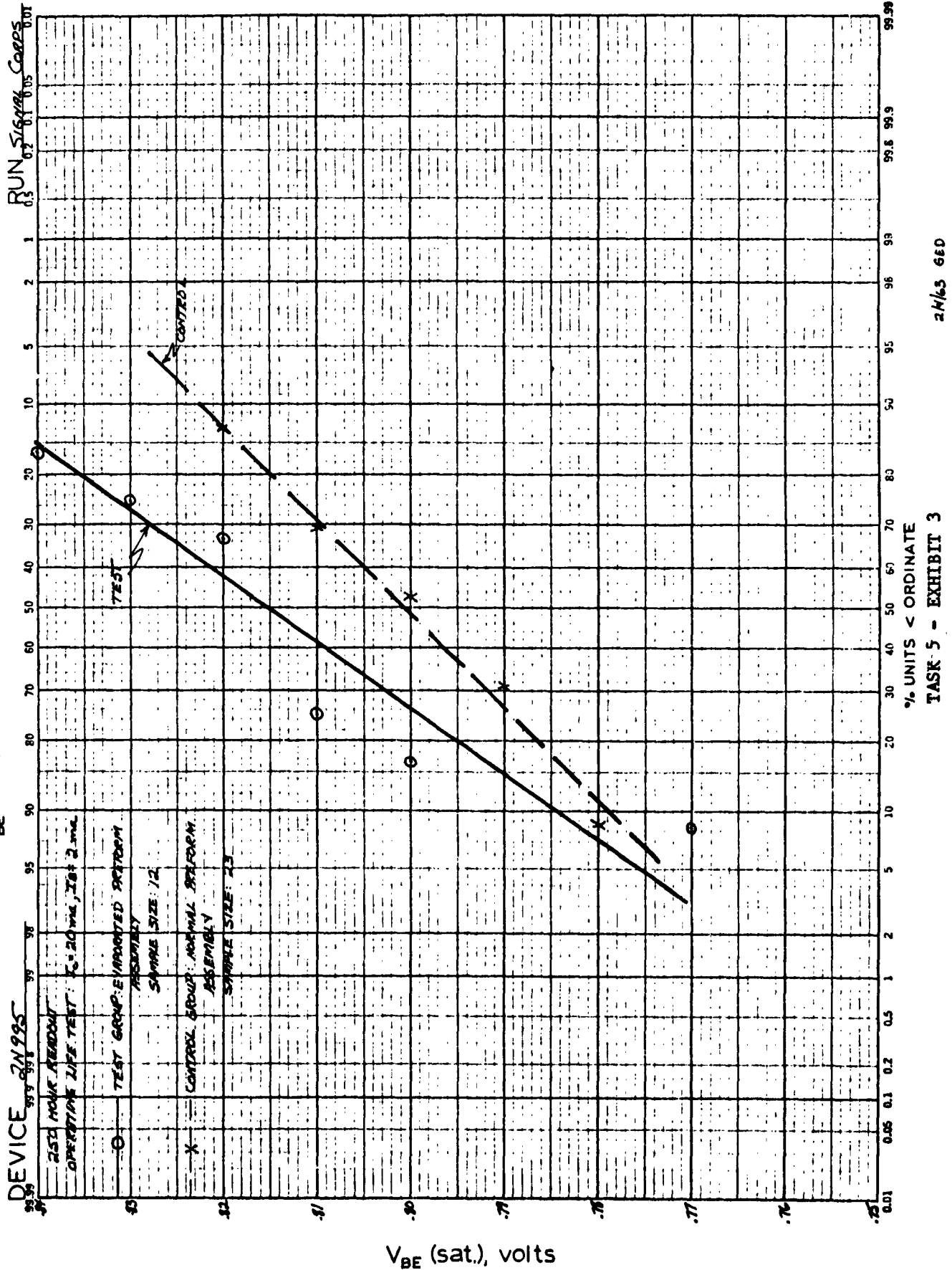
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V<sub>BE</sub> (sat.) vs FREQUENCY DISTRIBUTION



K-Σ PROBABILITY SCALE 359-23  
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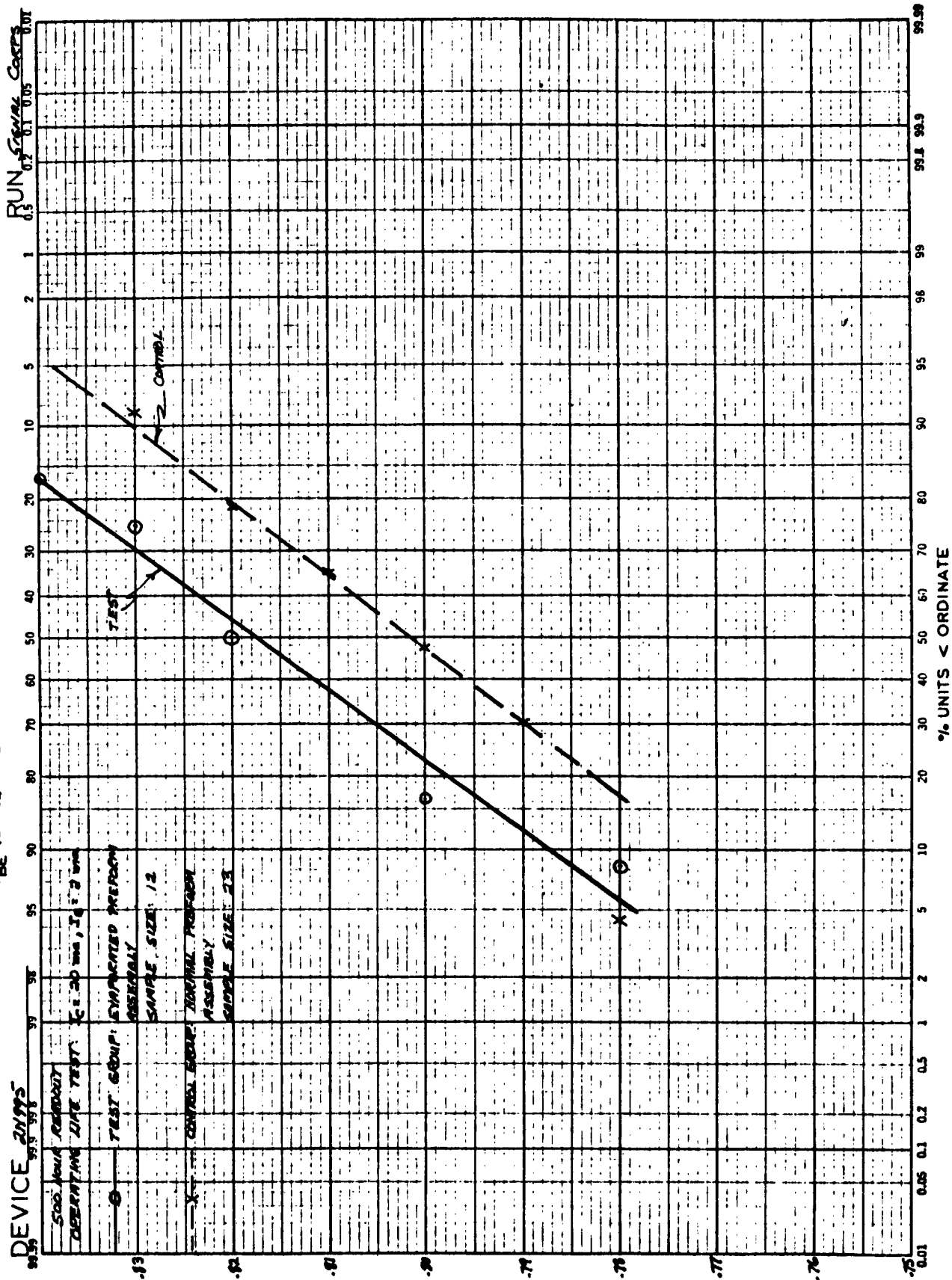
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KOE PROBABILITY SCALE 359-23  
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# EXPERIMENT PREFORM ELIMINATION

$V_{BE}$  (sat) vs FREQUENCY DISTRIBUTION



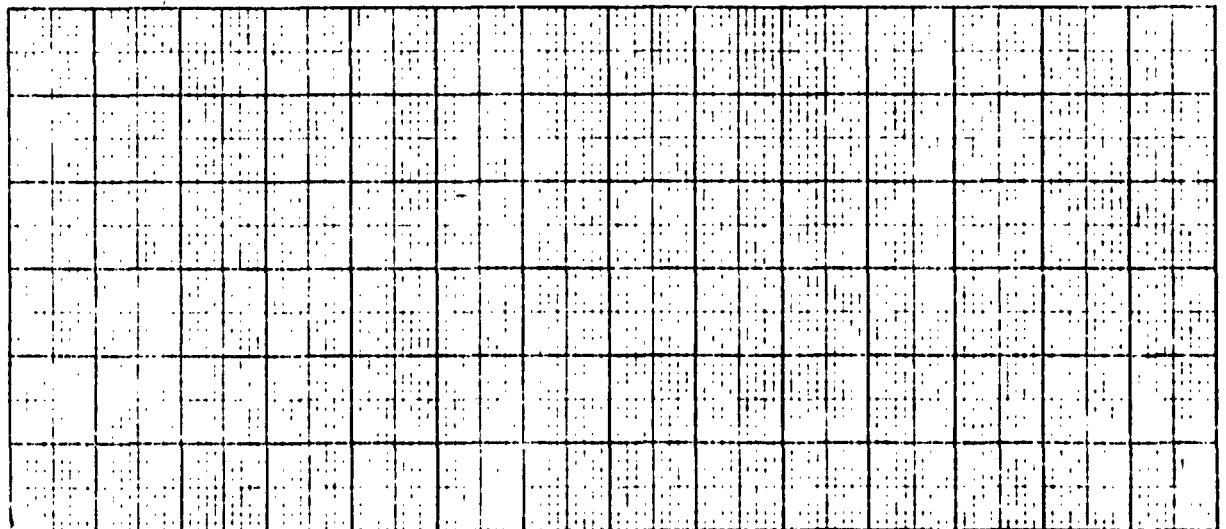
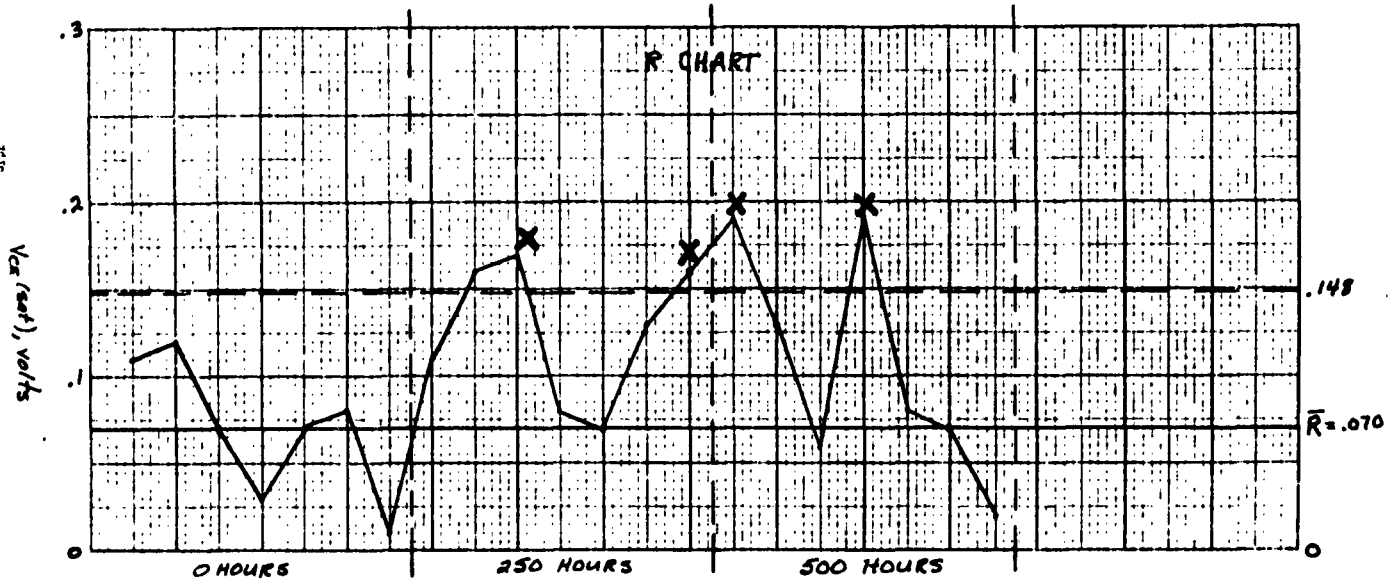
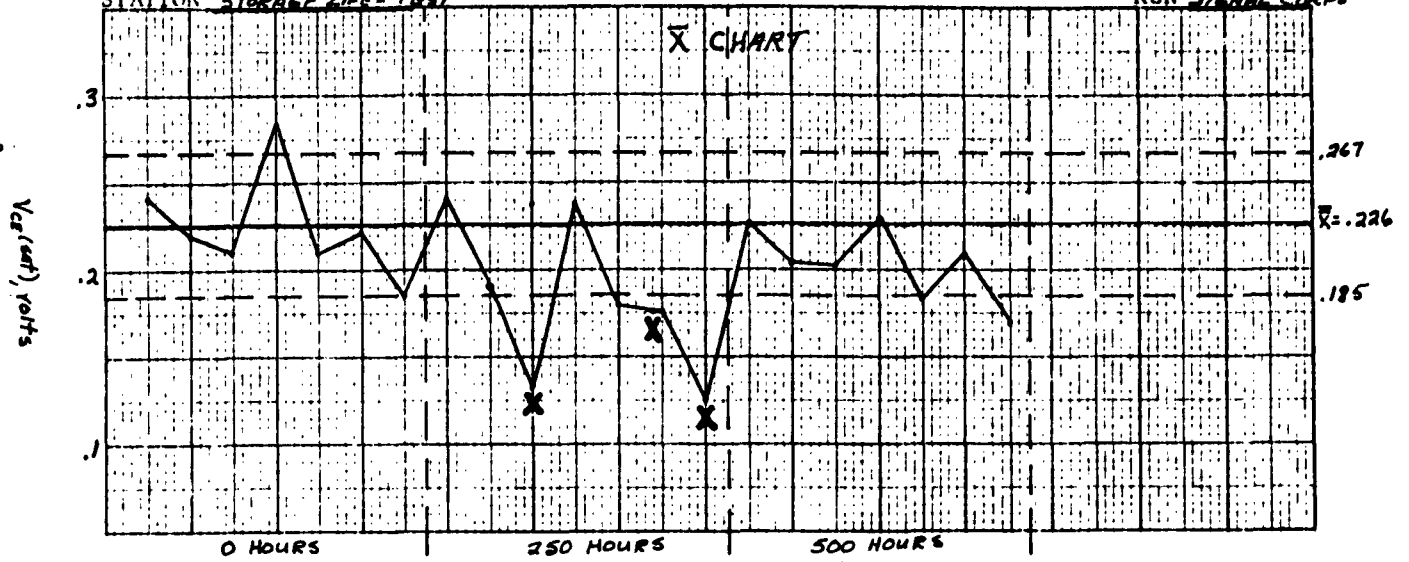
# $\bar{X}$ and R CHART

EXPERIMENT PREFORM ELIMINATION  
STATION STORAGE LIFE - TEST

DEVICE 1741(2N995)  
RUN SIGNAL CORPS

CODER BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS  
PAID TO U.S.A.

NO. 21.231. 20 PLS. 3.005 TO 1.000. P074 M115  
3 SECTIONS OF 30 DIVISIONS EACH BY 140 DIVISIONS.



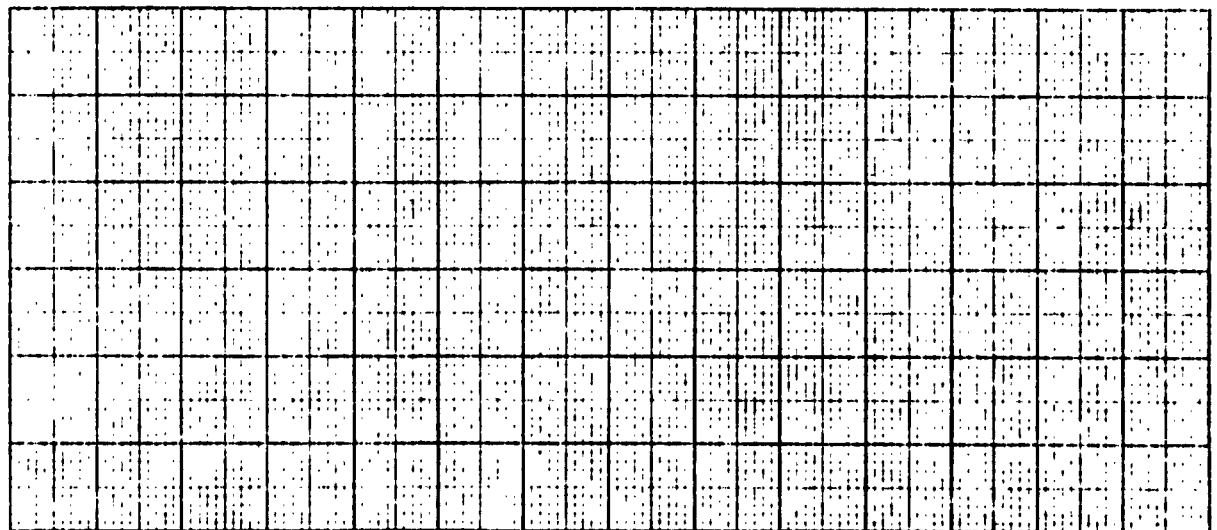
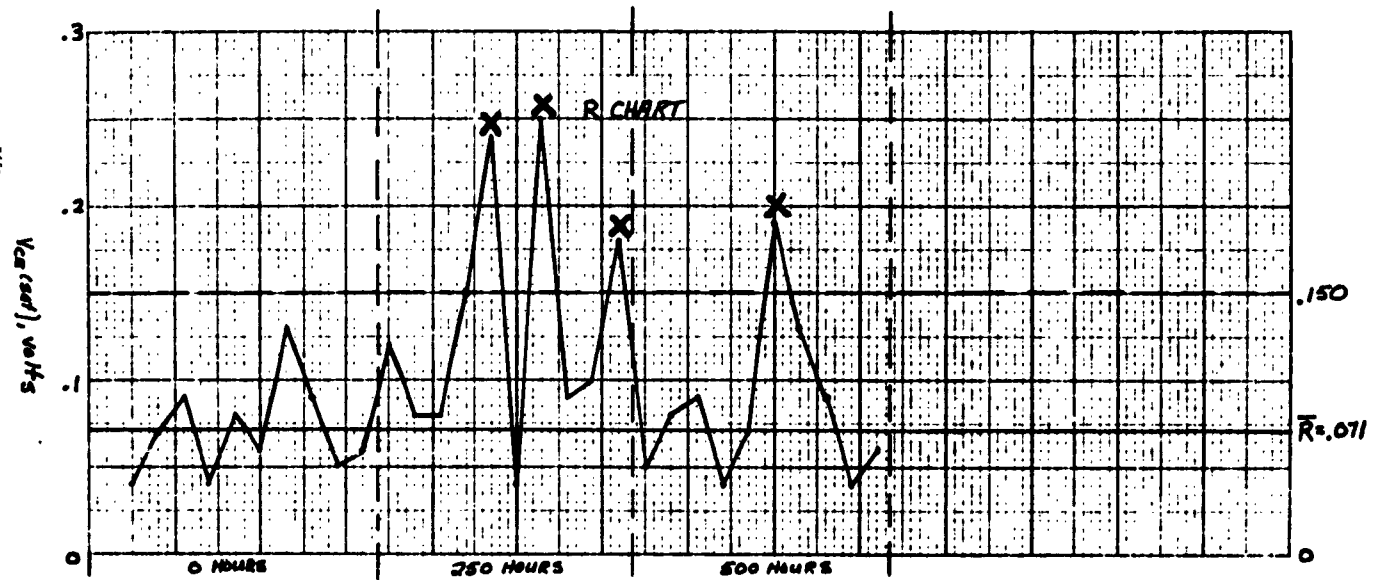
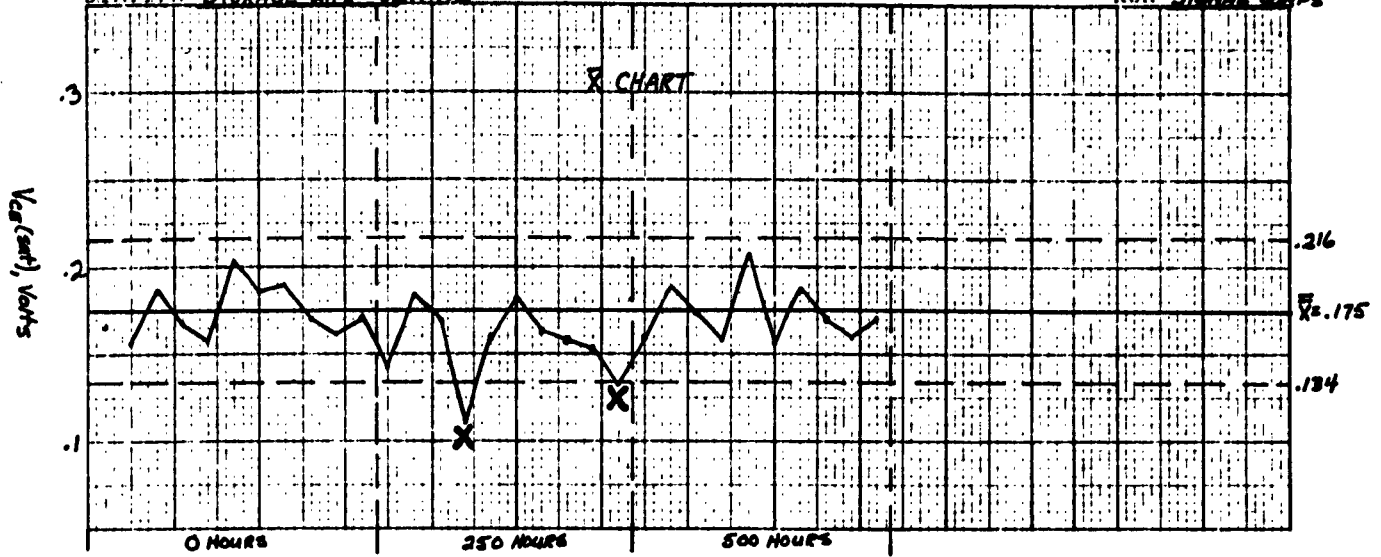
# $\bar{X}$ and R CHART

EXPERIMENT PERFORM ELIMINATION  
STATION STORAGE LIFE - CONTROL

DEVICE 1741 (2N795)  
RUN SIGNAL CORPS

CODING BOOK COMPANY, INC. NEW WOOD, MASSACHUSETTS  
PRINTED IN U.S.A.

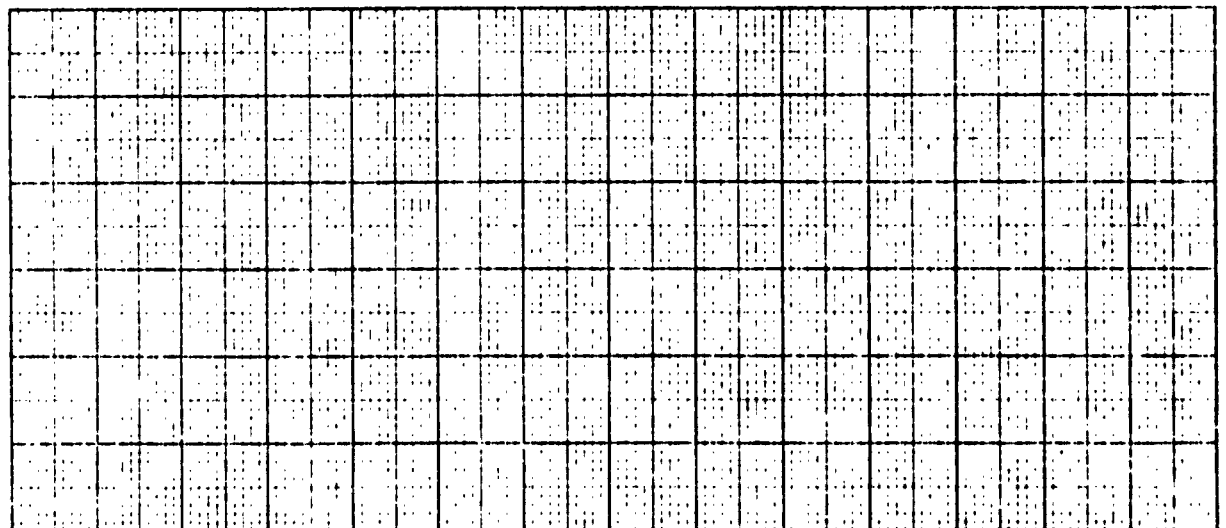
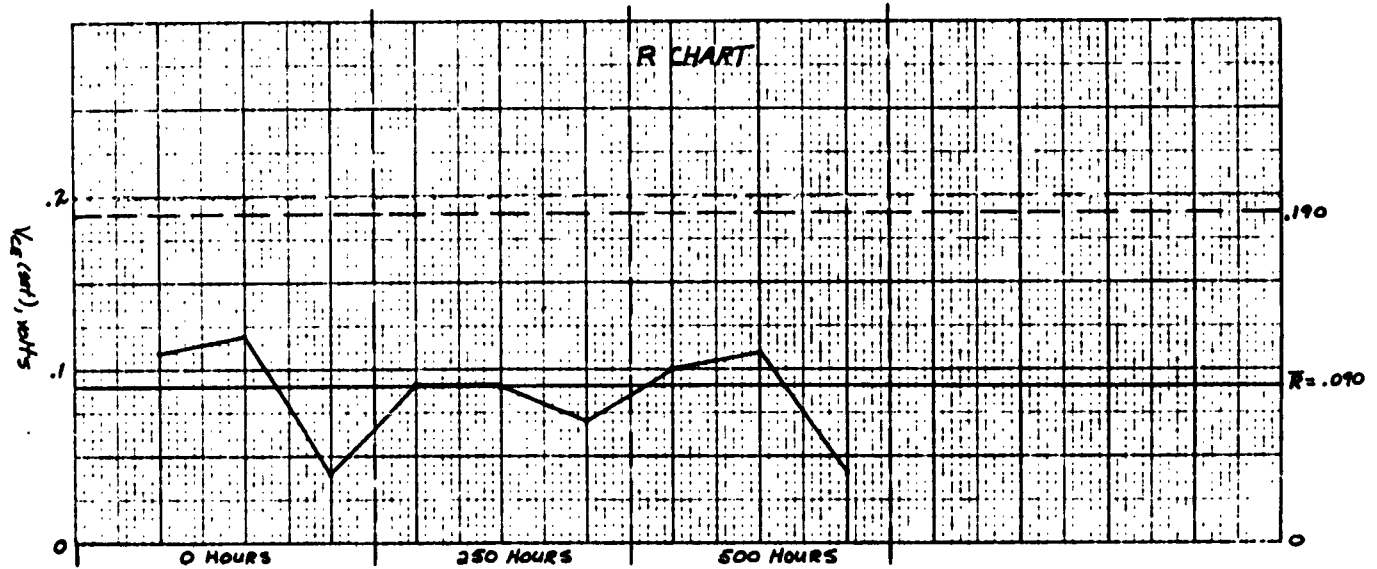
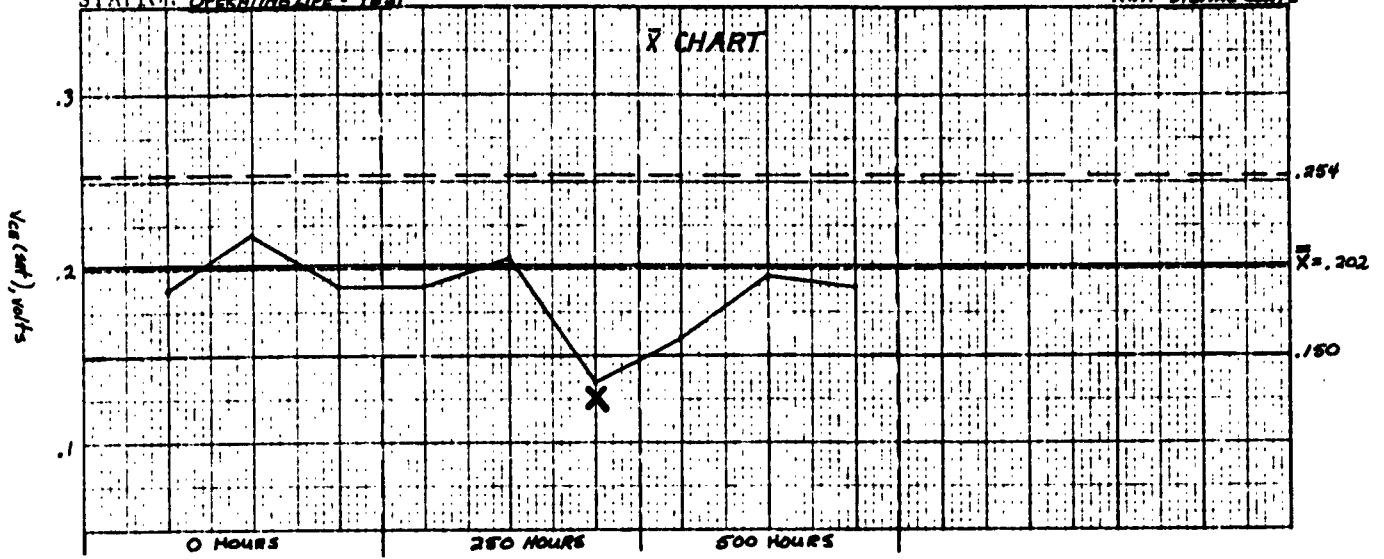
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3 SECTIONS OF 30 DIVISIONS EACH BY 140 DIVISIONS.



# $\bar{X}$ and R CHART

EXPERIMENT ~~TRANSFORM ELIMINATION~~  
STATION OPERATING LIFE - TEST

DEVICE 1741 (30795)  
RUN SIGNAL CORPS



CODER BOOK COMPANY, INC. NORWOOD, MASS. 01908  
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NO. 31231. 30 DIVISIONS EACH BY 140 DIVISIONS.  
3 SECTIONS OF 30 DIVISIONS EACH BY 140 DIVISIONS.



# $\bar{X}$ and R CHART

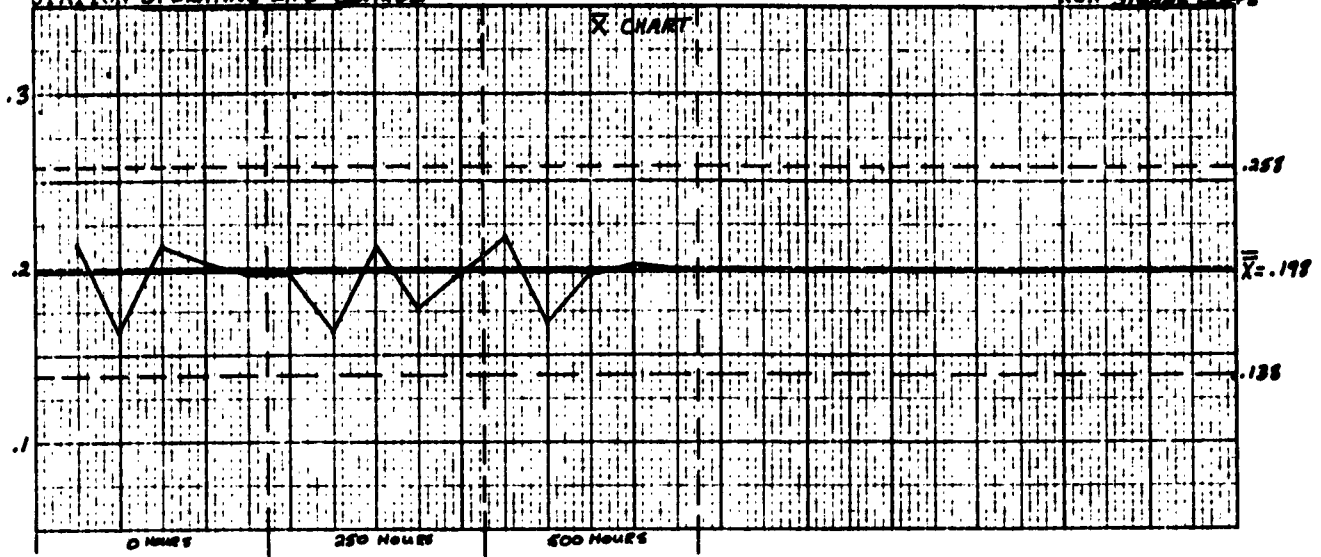
EXPERIMENT PREFORM ELIMINATION  
STATION OPERATING LIFE-CONTROL

DEVICE 1741 (24795)  
RUN SIGNAL CORPS

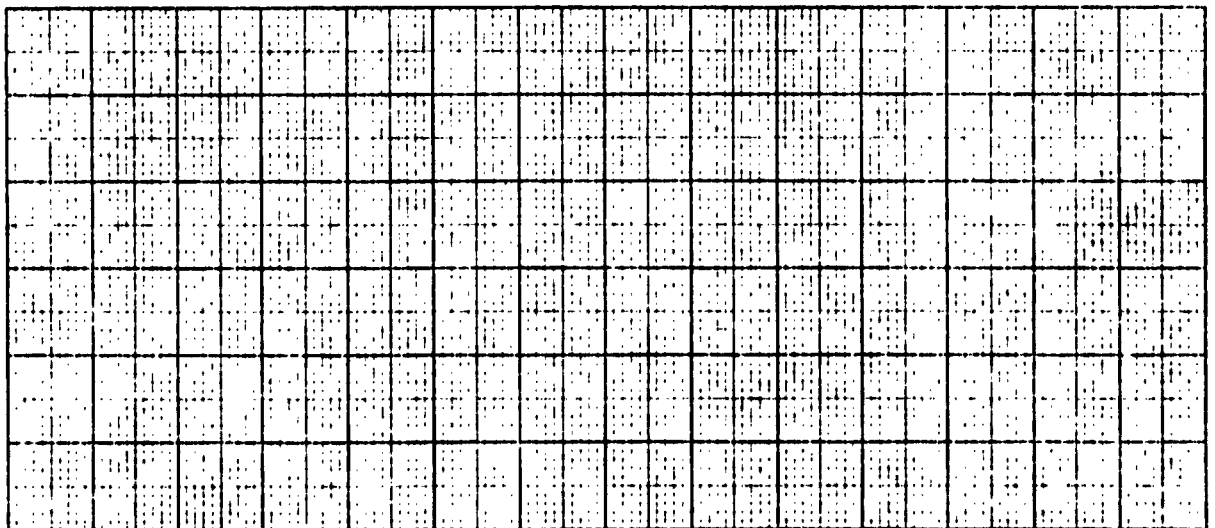
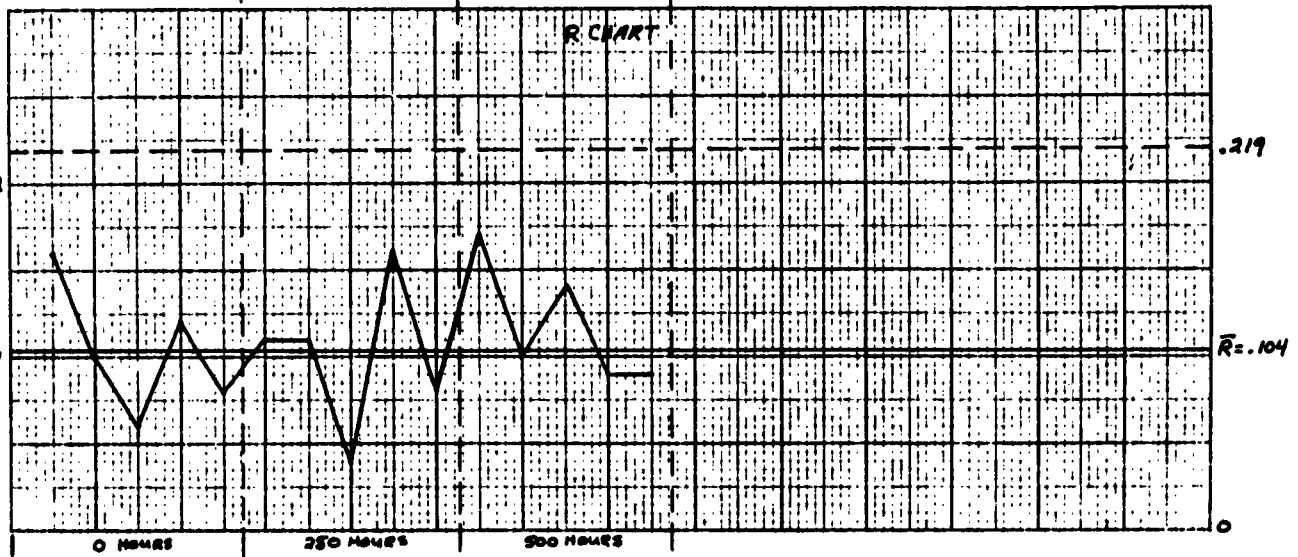
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PRINTED IN U.S.A.

NG. 31.231. 20 DIV. 3 ON 5 VOLT. 20 DIV. 3 ON 5 VOLT.  
3 SECTIONS OF 80 DIVISIONS EACH BY 140 DIVISIONS.

$V_{ce}$  (cent), volts



$V_{ce}$  (cent), volts



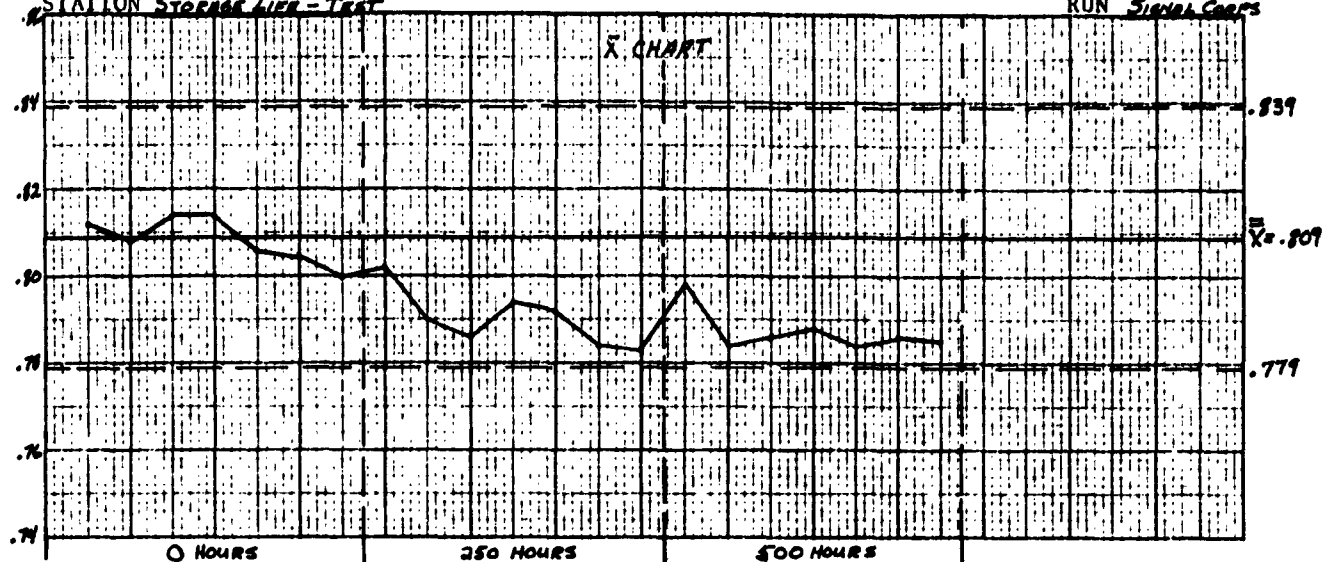
# X and R CHART

EXPERIMENT PREFORM ELIMINATION  
STATION STORAGE LIFE - TEST

DEVICE 1741 (2N998)  
RUN SIGNAL CORPS

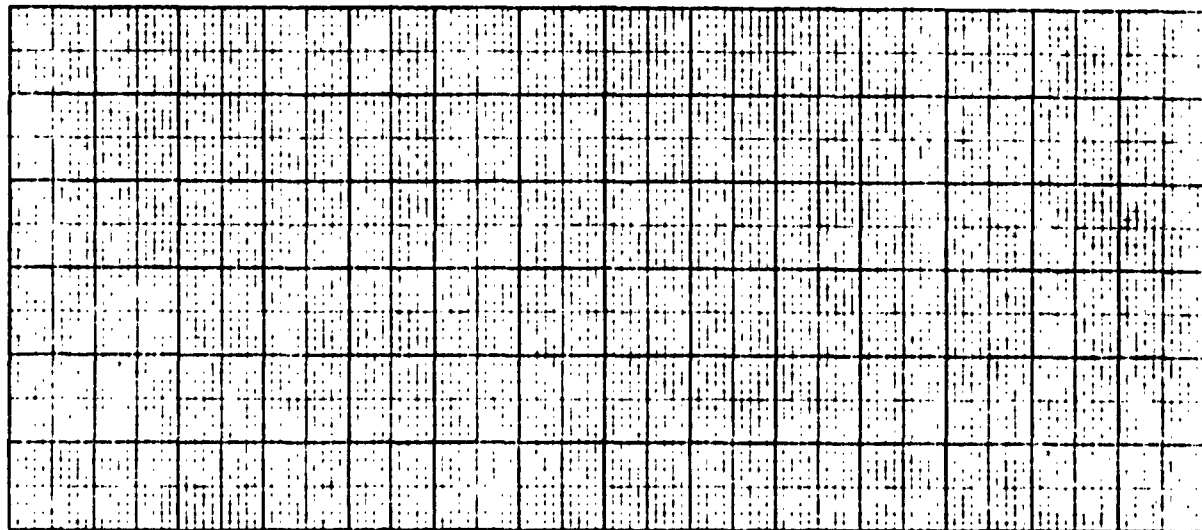
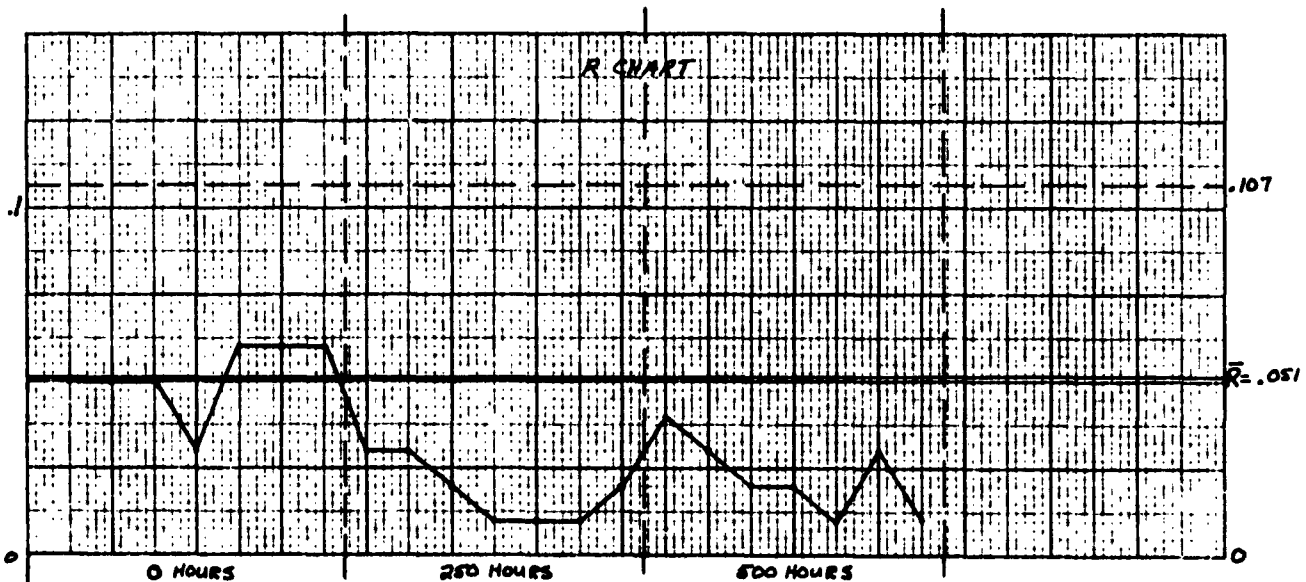
REPRODUCED IN U.S.A.

$V_{GS}(avg)$ , volts



$V_{GS}(avg)$ , volts

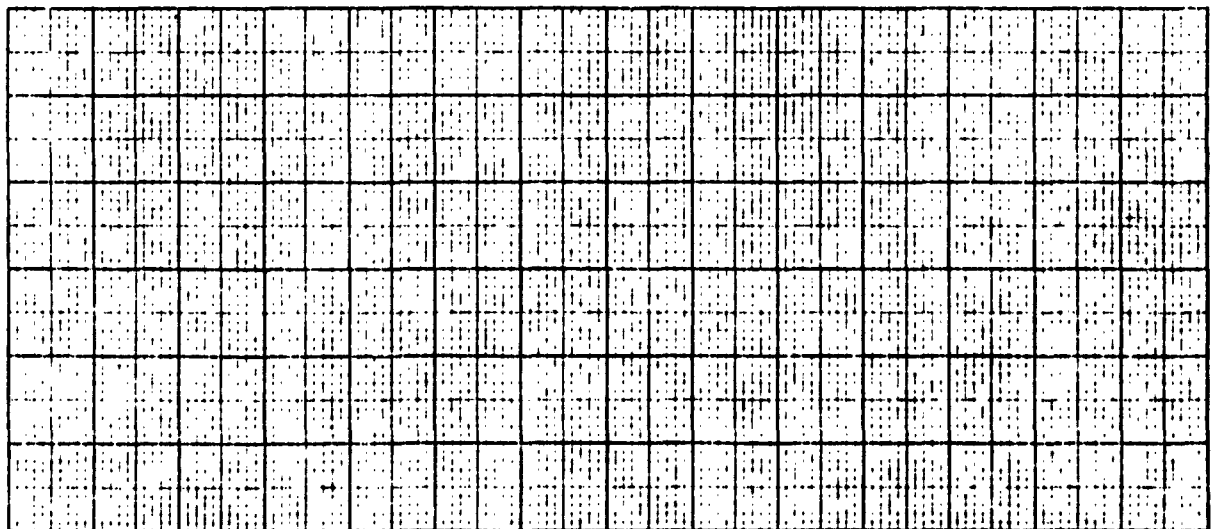
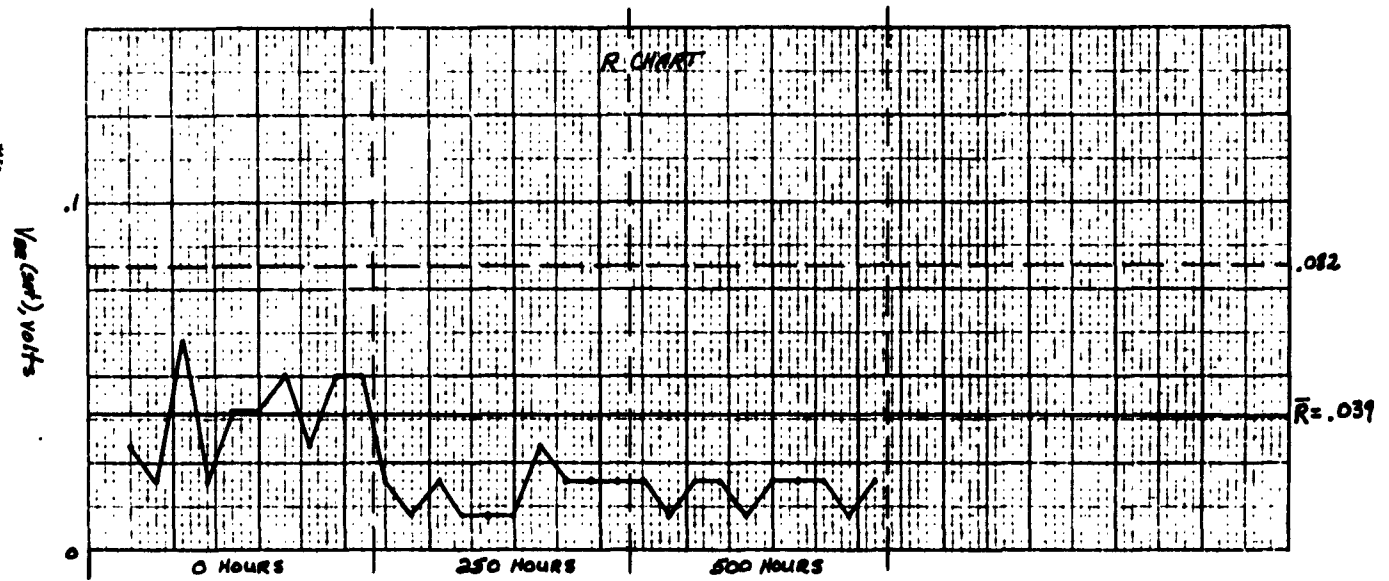
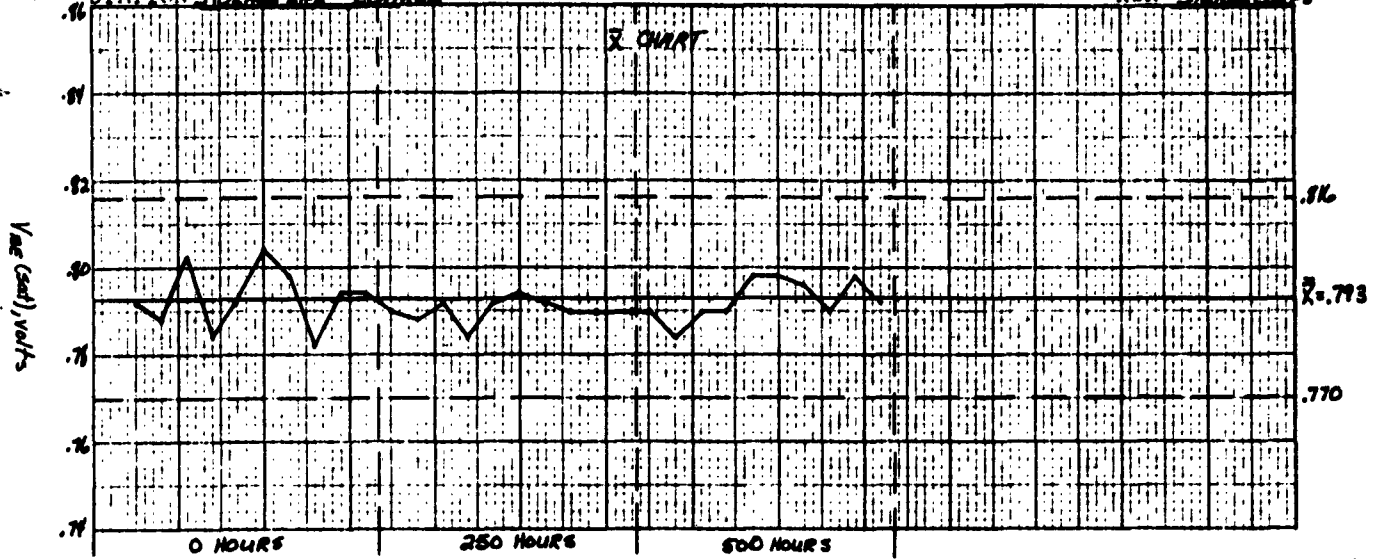
REPRODUCED IN U.S.A.  
3 SECTIONS OF 30 DIVISIONS EACH BY 140 DIVISIONS.



# $\bar{X}$ and R CHART

EXPERIMENT PREDORM ELIMINATION  
STATION STORM LINE - CONTROL

DEVICE 1741 (24995)  
RUN SIGNAL CORPS



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MADE IN U.S.A.



NO. 31.231. 20 DIVISIONS PER INCH, BOTH WAYS.  
3 SECTIONS OF 50 DIVISIONS EACH BY 140 DIVISIONS.

# X and R CHART

EXPERIMENT PREFORM ELIMINATION  
STATION OPERATING LIFE-TEST

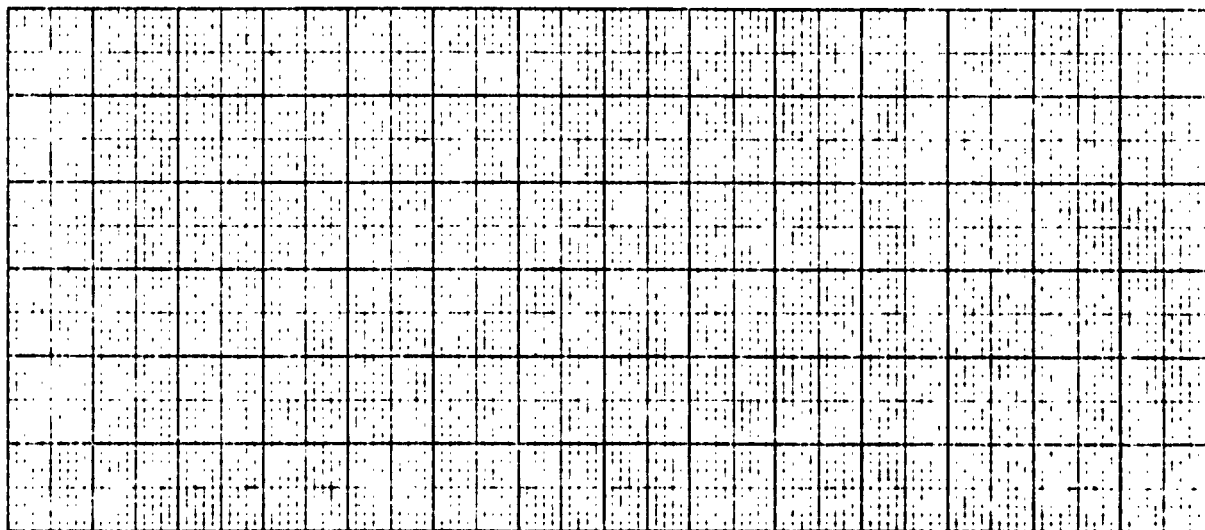
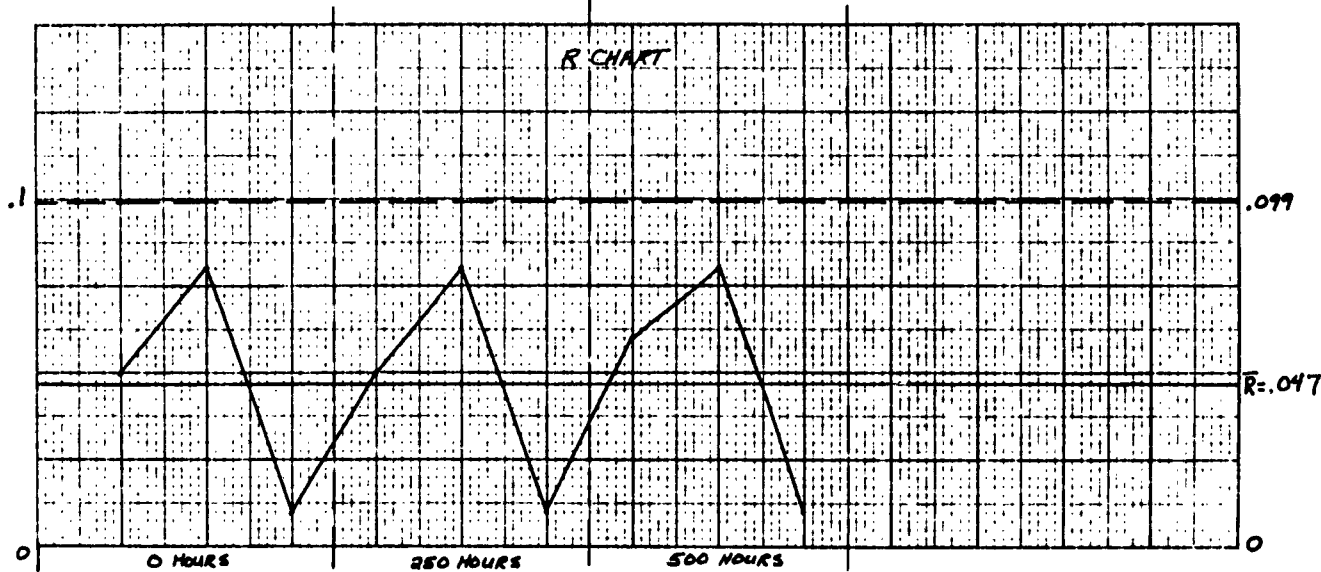
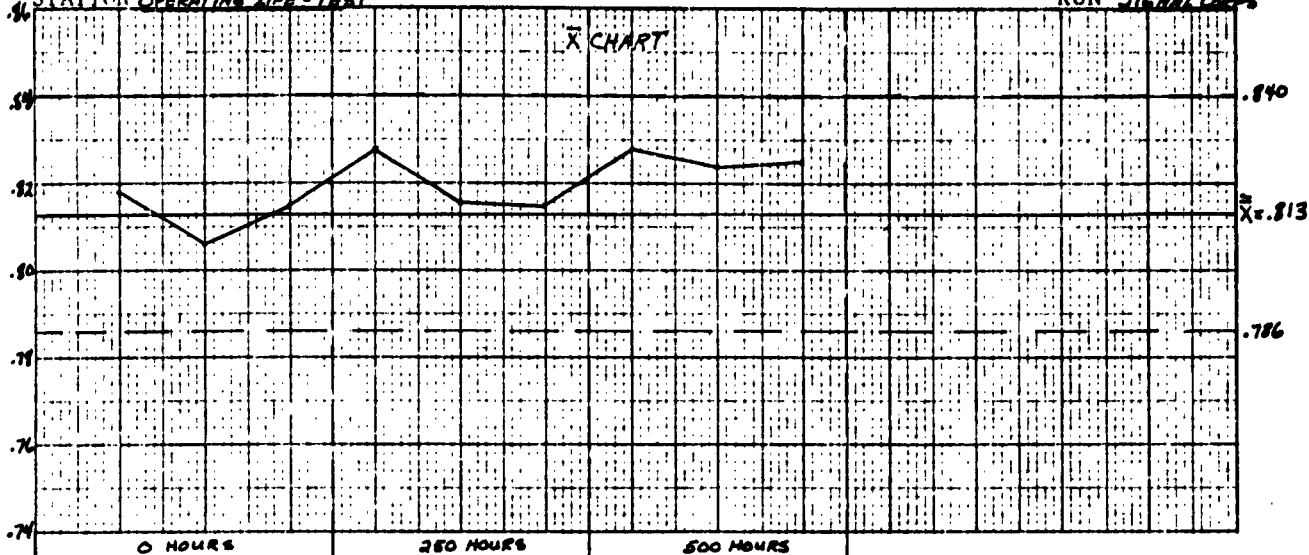
DEVICE 1741 (28995)  
RUN SIGNAL CORPS

CODER BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS  
PRINTED IN U.S.A.

NO. 21.231. 20 DIVISIONS PER INCH. 100% P.D.M. WAVE  
3 SECTIONS OF 50 DIVISIONS EACH BY 140 DIVISIONS.

$V_{GS}(sat)$ , volts

$V_{GS}(sat)$ , volts



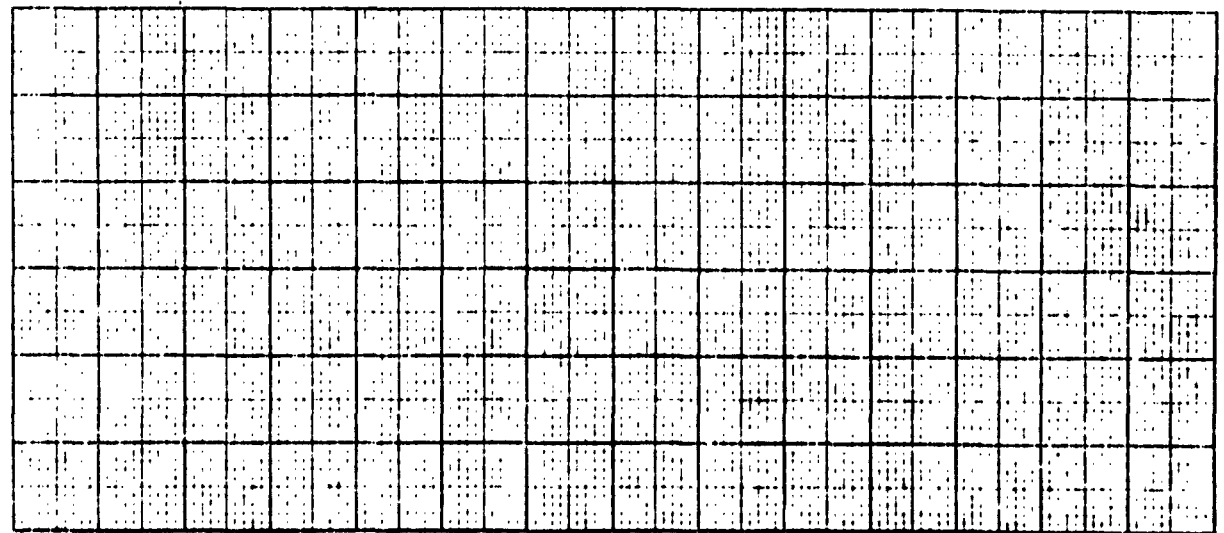
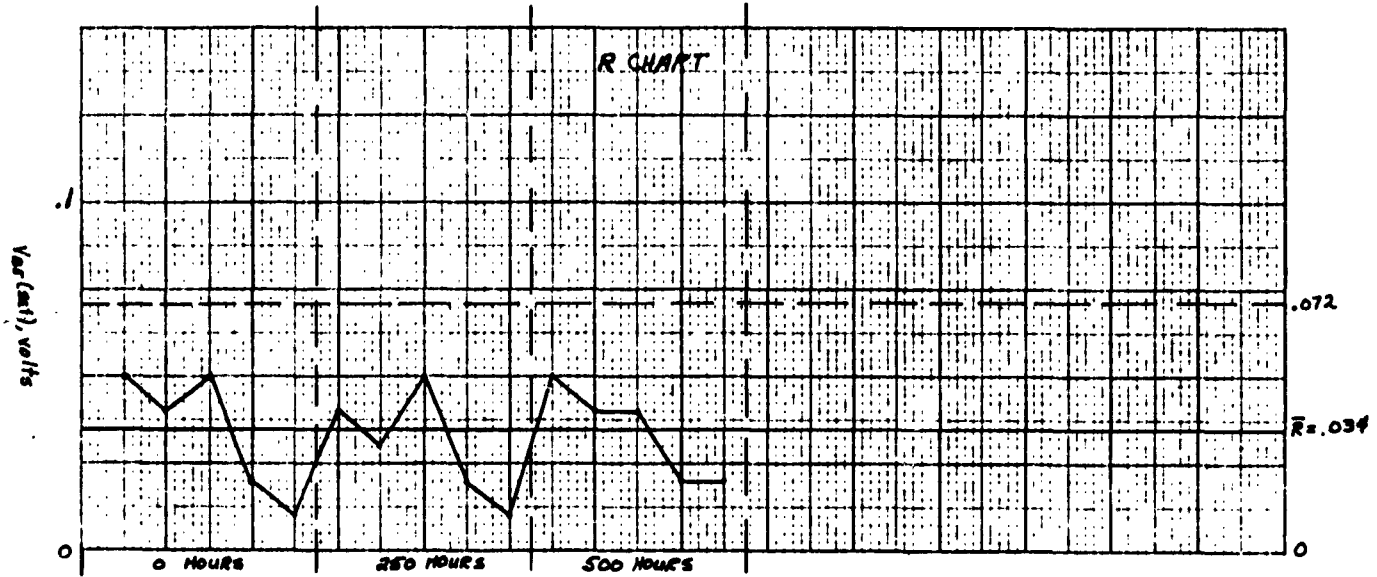
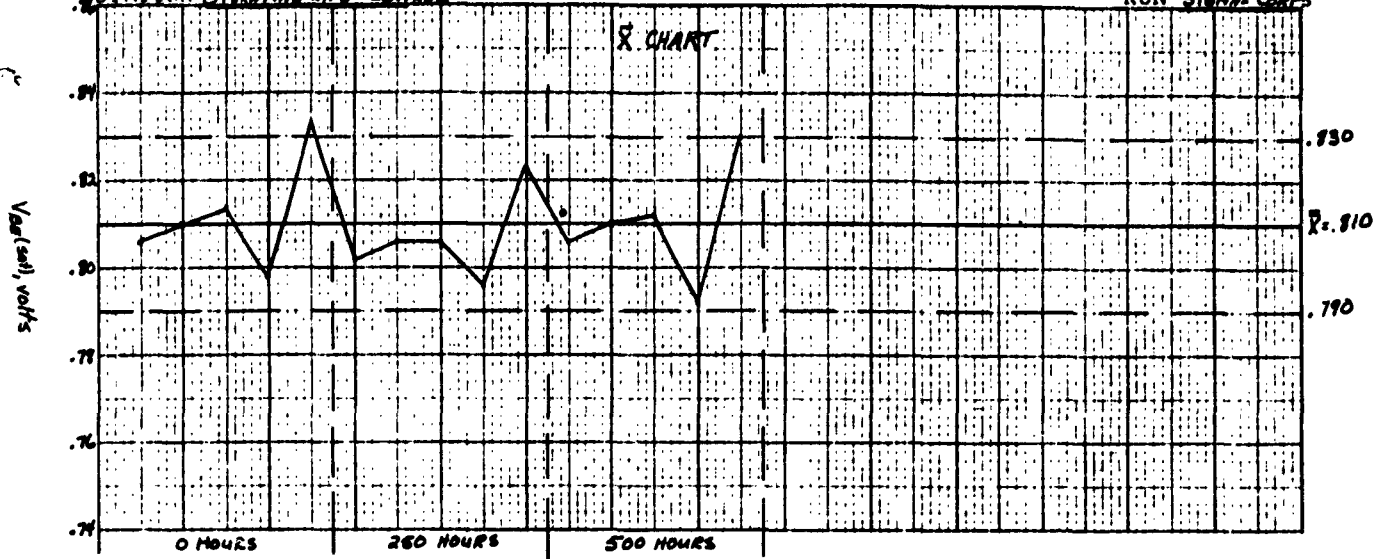
# $\bar{X}$ and R CHART

EXPERIMENT PERFORM ELIMINATION  
STATION OPERATING LIFE - CONTROL

DEVICE 1741(20776)  
RUN SIGNAL CORPS

CODER BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS  
U.S.A.

NO. 21.231 3070 4 30 27 100 2014 4115  
3 SECTIONS OF 40 DIVISIONS EACH AT 140 DIVISIONS.



TASK 5 - EXHIBIT 4

TASK 5 - EXHIBIT 5

TABLE I

STORAGE LIFE TEST

Test	Comparison	$n_x$	$n_y$	df	t	$S_t$	F(x/y)	F(y/x)	$S_F$
1	$V_{CE}$ (sat) 1, TP1, A vs B	322	39	43.3	-4.30	99.5%	-	1.88	99%
2	$V_{CE}$ (sat) 2, TP1, A vs B	322	39	38.5	-7.57	99.5%	-	17.8	99%
3	$V_{BE}$ (sat), TP1, A vs B	322	39	42.8	-6.89	99.5%	-	2.07	99%
4	$V_{CE}$ (sat) 1, A, TP1 vs TP2	322	322	566	49.4	99.5%	-	2.17	99%
5	$V_{CE}$ (sat) 2, A, TP1 vs TP2	322	322	631	1.53	No	-	1.33	95%
6	$V_{BE}$ (sat), A, TP1 vs TP2	322	322	325	4.89	99.5%	-	153	99%
7	$V_{CE}$ (sat) 1, B, TP1 vs TP2	39	39	57.6	3.29	99.5%	-	3.82	99%
8	$V_{CE}$ (sat) 2, B, TP1 vs TP2	39	39	77.8	.660	No	1.10	-	No
9	$V_{BE}$ (sat), B, TP1 vs TP2	39	39	38.1	4.62	99.5%	-	495	99%
10	$V_{CE}$ (sat) 1, TP2, A vs B	322	39	41.0	-9.84	99.5%	-	3.30	99%
11	$V_{CE}$ (sat) 2, TP2, A vs B	322	39	38.8	-7.18	99.5%	-	12.1	99%
12	$V_{BE}$ (sat), TP2, A vs B	322	39	39.5	3.62	99.5%	-	6.68	99%

TASK 5 - EXHIBIT 5

TABLE II

OPERATING LIFE TEST

Test	Comparison	$n_x$	$n_y$	df	t	$S_t$	F(x/y)	F(y/x)	$S_F$
13	$V_{CE}$ (sat) 1, TP1, A vs B	65	26	28.6	-1.16	No	-	6.02	99%
14	$V_{CE}$ (sat) 2, TP1, A vs B	65	26	25.2	-4.28	99.5%	-	116	99%
15	$V_{BE}$ (sat), TP1, A vs B	65	26	53.3	-3.05	99.5%	1.26	-	No
16	$V_{CE}$ (sat) 1, A, TP1 vs TP2	65	65	92.2	21.7	99.5%	-	4.45	99%
17	$V_{CE}$ (sat), 2, A, TP1 vs TP2	65	65	126.3	1.13	No	-	1.41	No
18	$V_{BE}$ (sat), A, TP1 vs TP2	65	65	68.4	2.29	No	-	29.9	99%
19	$V_{CE}$ (sat), 1, B, TP1 vs TP2	26	26	51.4	3.08	99.5%	-	1.23	No
20	$V_{CE}$ (sat), 2, B, TP1 vs TP2	26	26	52.0	.198	No	1.02	-	No
21	$V_{BE}$ (sat), B, TP1 vs TP2	26	26	43.8	3.92	99.5%	-	2.47	1
22	$V_{CE}$ (sat), 1, TP2, A vs B	65	26	38.6	-7.79	99.5%	-	1.67	No
23	$V_{CE}$ (sat) 2, TP2, A vs B	65	26	25.3	-4.15	99.5%	-	80.1	99%
24	$V_{BE}$ (sat), TP2, A vs B	65	26	81.9	-1.31	No	15.2	-	99%

## SECTION IV

### IDENTIFICATION OF TECHNICIANS

In November and December of 1962, and January of 1963, 4680.6 hours were expended by Fairchild engineering and support personnel on this contract, exclusive of technical supervision whose time is accumulated in overhead accounts. Following is a list of key technical personnel and time expended by them.

#### SUMMARY OF HOURS CHARGED BY KEY TECHNICAL PERSONNEL

Arnold, S.	21.5
Botte, F.	4.0
Butts, W.	275.0
Carmichael, E.	23.0
Corzine, J.	221.0
Crosby, R.	20.5
Davis, G.	85.5
Finlayson, M.	191.0
Hammer, R.	120.0
Hippert, E.	405.0
Kobrin, D.	178.0
Levitsky, M.	14.0
Martin, D.	307.0
Murphy, J.	66.0
Myers, D.	120.0
Rollason, P.	138.0
Schroeder, J.	327.0
Sentous, J.	24.0
Shea, D.	28.0
Sussenberger, J.	37.0
Warren, W.	438.0
Weiler, P.	143.0
Weller, A.	3.0